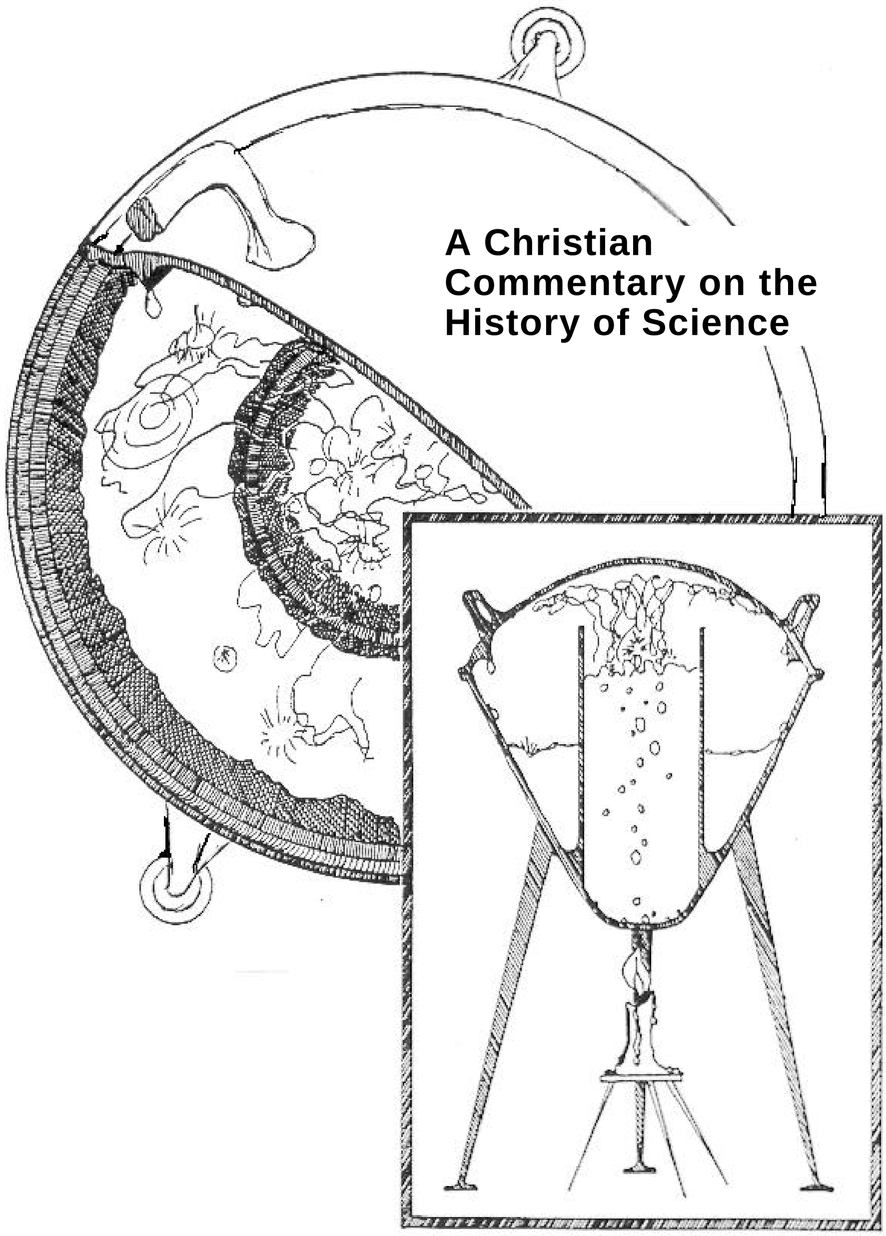
SEPARATE FROM HIS WORD



A Christian Commentary on the History of Science

MARTIN P. SPONHOLZ

Martin Luther College

SEPARATE FROM HIS WORD

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This history of science reflects the historical portion of a ninth grade course, Scientific Thought, developed at Luther High School, designed to be different from traditional ninth grade courses in science, designed to show students how human beings develop theories and laws of science, and designed to show how these theories and laws change in the endless struggle to explain the natural world. I am grateful to Luther High School for the eleven year experiment and especially want to thank David Kuske for his encouragement to pursue new ideas in teaching science for the discerning mind.

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Most of the graphs and figures were developed and drawn on a Macintosh LC II computer with Claris Mac Paint software by Mark P. Sponholz. The entire text was organized and printed with Claris Works. Without the modern computer and the young gifted mind that quickly knows how to use the tools of the computer this would have been a very gray book.

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To God alone the glory.

Martin P. Sponholz

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PREFACE

Two very different and very useful approaches exist in the teaching of science, that of the naturalist and that of the scientist. Generally, the view of the naturalist is used in elementary education; the view of the scientist, in secondary education. It is in the transition between these two points of view, which takes place in the junior high school, especially in Christian education, where neglected topics like history and philosophy with respect to science are vital.

The naturalist accepts nature as it is and is perhaps the closest to the material truth of nature. He is a friend to nature and a friend of nature. Here is truly where the child can see God's wondrous creation: the intricacies, the complexities, the beauty, the special care of God for all things. Usually stressed in the early grades are the migration of birds; identification of animals; habits of special animals; some details of insects and their life changes; studies of water, rivers, air, clouds; identification of plants, and the understanding of our bodies and the workings of all the organs to keep us healthy.

This, of course, is far from a complete list, but the naturalist's approach is clear with this list. The student is shown the many wonders of nature, which God has given us and has put within our dominion. Nature is accepted as it is. God is trusted. God's power and wisdom can be clearly shown to the student. God's special care for all His creatures is obvious. "As long as the earth endures, seed time and harvest, cold and heat, summer and winter, day and night will never cease (Gen. 8:22, NIV)." When nature is viewed as it is, nature truly testifies of God.

This first approach to science is a necessary first step. In fact, as far as science education goes, this is the most important step: that all things of creation are seen as the blessings of God. "For since the creation of the world God's invisible qualities--his eternal power and divine nature--have been clearly understood from what has been made. . . (Rom. 1:20, NIV)." Thus, this naturalist's view gives the strongest stand against evolution that is possible outside God's inspired Word. This simple "birdwatcher's" view of nature provides great strength to the human reason of our children.

As a child grows in knowledge, his curriculum changes to the view of the scientist. The wonders of God's creation and God's power and wisdom in sustaining His creation certainly can still be taught, but now man's imprint is on all of the explanations. Rigid definitions, classifications, formulas, and abstractions of nature are taught. This usually creeps into the curriculum, starting with the fifth grade. In high school courses, in biology, chemistry, and physics, the naturalist is lost. Mathematical models, the laws of science, and complex classifications rule and almost dictate to nature how it must be. Laboratory reports in scientific tradition explain reasons for experimental error instead of accepting nature's differing from the laws. Prediction and control are the ultimate hope of every endeavor of science. This can be achieved only by the scientist, not by the naturalist. It is this view in today's scientific world that our older children must finally work with. A sad truth, however, plagues this approach. Many scientists, in explaining how nature must be, embrace evolution, a philosophy that denies God's almighty hand in creation.

The Christian scholar knows the truth of a basic premise of the scientific approach. There must be order in nature. God has created all with purpose and meaning. His six days of creation testify to a carefully created order. There is no doubt of the Christian influence

on the scientific age. When the Reformation restored a trust in God's Word, the century that followed was unprecedented in its success at prediction and mathematical application of the complex natural world. People who believed in a God of order truly found a predictable world. The fears, skepticism, and even hopelessness of today's researchers in science may truly be the results of many scientists' belief in evolution and order by chance. The Christian, however, never need fear that research findings of material truth would ever contradict the revealed truths in the Bible relating to the natural world.

At the same time, however, our certainty of the truth with respect to the material truth as seen by the laws of science accepted today is not as certain as textbooks would have us believe. Science is an entirely human endeavor. Its laws are intellectual models of artistry. It can be shown historically that each age of science has worked within its own circles of reason as supported by the paradigms of the age. Many times scientists promoting new revolutionary theories found it difficult to replace accepted laws until the old scientists were replaced by the younger generation. In time the laws of science change as new theoretical artistry explains new ideas and provides new hope for solving the problems of its age. Even scientific facts change under the interpretations of new theories and new laws.

Sadly, the educators of the age instill in the minds of youth a feeling of certainty with science that does not exist. By emphasizing the errors of the past age without teaching how well old concepts explained what was required of them in their age, the student is misled to think that scientific methods provide the way toward certain truth. Old concepts such as phlogiston, epicycles, the four elements (earth, fire, air and water), continuous matter, chemical elective affinity, force at a distance, and amber effects were extremely successful in their day.

Before the Christian starts teaching scientific reasons which point to error in evolution, he should teach that the laws of science are not identical with the order God placed in His creation. Too often a rigid scientific approach to the subject leaves a student with the idea that the laws of science are proved. He spends his junior and senior high school and college years memorizing the laws of science, reworking experiments demonstrating these laws, and concludes that these laws must be proved. Yet the scientific community is struggling desperately to change them. No scientist dare claim such certainty for the things called laws. And no true scientist does! Therefore, the Christian educator must teach the history of science and let some uncertainty rightly emerge.

In every endeavor, where reason plays a major role, mankind brings his beliefs as well as his unbeliefs. The Christian is also faced with separating belief from unbelief. I am not sure we can do that in science. Atomic laws of chemistry originated in the evolutionary ideas of Democritus. Yet it would be unwise to cancel chemistry classes. Genetic research and many viral studies have roots in Darwin's ORIGIN OF SPECIES, but do not cancel biology classes or cause people to refuse vaccinations. Every scientist, in whatever branch he works, knows he works with over-simplifications, approximations, and even contradictions. Oil in many cases is discovered by using theories of evolution, but that success does not prove man's reason, but rather God's grace in spite of man. We should teach that the material successes are the bountiful gifts of our Lord rather than the certainty and sufficiency of man's wisdom.

In the transition from the little child's naturalist view to the mature student's scientific view, historical changes of scientific thought must be taught. The student must witness some uncertainty of the laws of science and the artistry of the scientists of every age. Much would be gained by teaching how well Ptolemaic astronomy worked and can still explain the motions of the heavens even when today a better Copernican view has replaced it.

The historical setting of the change would reveal more about the nature of the subject of science and the methods of the scientists than any laboratory experiments during these transitional years of a student. A historical view of the changing ideas of scientists is worth far more in the conflict with evolution than some law of physics for which the final pages of research and debate remain unfinished. The understanding of some misplaced fossils remains useless without first teaching the nature of science. The interpretation of stratified bedrock in a scientific sense has no meaning without understanding the paradigm on which such scientific interpretations are based. If there exists no desire to show a student the structure of scientific thought in its historical setting, it would be better to leave him with that great naturalist view his lower grade teacher gave him than to give him the wrong view that the laws of science are certain, proved and apart from human history.

But all these views of nature, that of the naturalist, the scientist, and the history of science, are pale compared to God's clear Word in the Bible. God's holy writers repeatedly show God governing all things according to His discretion. It remains a strong Lutheran doctrine, especially in the scientific age, that we understand and live by faith. It is to the necessity of understanding historical changes of scientific thought by the Christian elementary and secondary teachers that this history of science, I pray, will give some answers and raise some questions.

SEPARATE FROM HIS WORD

THE BEGINNINGS OF SCIENCE:
"Let there be . . .," Chapter 1

We see no apparent beginning of science. There was no time when people did not think of nature or about its workings. There was no time when people did not make use of nature, or try to manipulate it, or control it to their desire. Some historians, however, like to think of science as starting with Max Plank or Albert Einstein, since only then did the mathematics of four dimensions yield to the space and time contraction of nature in its relativistic form, not as the absolute abstraction invented in the minds of men like Newton or Leibnitz. Some like to think of science starting with Galileo, giving him credit for inventing empirical or experimental science. Still others stretch back to Thales, beginning with his interpretation of the cosmos independent of the Greek mythical gods.

Science is a human activity. Science is a changing body of knowledge based on human attempts to explain the natural world in which our Lord has placed us. Science, so dependent on human thought, certainly existed in different forms as early as mankind thought.

God's Word shows us Adam, the first man, created from dust, a vegetarian, a gardener, with mental ability and a part of the entire creation, declared by the Creator as "very good." Modern anthropologists want us to accept their belief that the first human descended from an ancestral ape, a flesh eater, a hunter, with extremely low mental capabilities, evolving to his present state. This is quite a contrast. It is important to know our heavenly Father's truth of the past as the key to understanding the present. It is likewise important to know that our weak sin-stained efforts to understand things of nature are separate from the Bible.

In reaching backward, I have always been skeptical of reconstructions of the past, particularly from broken dishes, broken pottery, and fallen buildings. How are we sure of our interpretations? It is difficult as a father of several small children, when considering the incredible number of broken dishes, pots, and pans we've sent to the town dump, to believe an archaeologist a thousand years from now will be able to reconstruct my life style. Surely the magnetic impulses saved in computer storage systems will not survive the thousands of years. When an armless nude Venus is dug up, was it a work of art, an advertisement for an ancient brothel, or both? When it comes to the history of science, it's man's understanding of nature we look for; and without ancient written documents ideas of the mind are nearly and perhaps completely impossible to grasp.

1. BIBLICAL BEGINNINGS

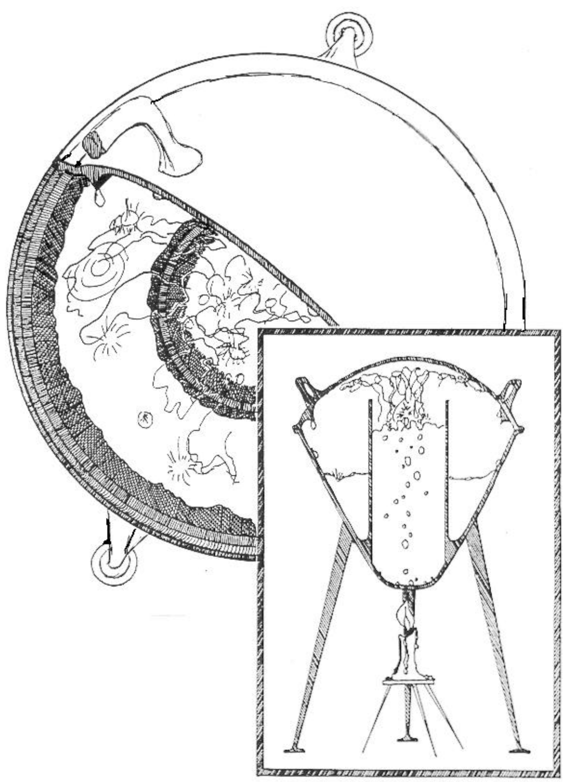
In the very first chapters of the Bible, Moses describes the early people's understanding and manipulating things of nature. We see them involved in agriculture, music, medicine, metal working, weaving, the complex chemistry of color dyeing, perfumery, glass making, and brewing. Moses remembers individuals by name. It is written that Adam named all the livestock, all the beasts of the field, and all the birds of the air. As keeper of the Garden of Eden, Adam could pass on to his children agricultural knowledge and skill for both herbal and animal production. Cain is mentioned as a builder of cities. Jabal is remembered for his skill as a herdsman, Jubal as the father of all who play the harp and flute, and Tubal-Cain as a toolmaker using bronze and iron.

It is significant that the science of archaeology identifies the Bronze Age and the Iron Age as two distinct periods of human culture. The Bronze Age began when bronze, an alloy of copper with tin, was first used to make tools around 3000 B.C. The Iron Age began in some places in the ancient world as early as 1000 B.C. when technology developed to give consistently hardened tools made of iron. Yet Moses identifies both bronze and iron in use to the extent of making it noteworthy in the Bible at a time long before the Flood. Such is the scientific and technological genius of early man, created from dust, ruining himself by sin, working against his Creator, but graciously endowed by his Creator with a mind well capable of trying to understand the natural world around him and using it and to some extent controlling it.

2. EARLIEST TECHNOLOGY VERSUS SCIENCE

Much of what is mentioned here might be related to technology rather than science. However, a clear distinction between the two cannot be identified in the history of science. At times science cannot progress until a technological device has been invented such as a still, a microscope, or a telescope. At other times technology is seen as the fruit of science, like steam engines, electric lights, and microchips. Many times purely accidental discoveries are made, although these fade with the scholarship of hindsight.

FIGURE 1.1 SUMERIAN BOILING POT. [BR]



George Sarton, a Harvard scholar, an emigrant from Belgium, and a pioneer of the history of science as a separate discipline, identifies science as a human practice before writing. The human thoughts of the explanations of nature in pre-writing times, of course, are lost. We likewise may assume they existed in this most distant past; and when knowledge of nature was orally transmitted from generation to generation, men capitalized on their longevity, some nine hundred years per person for early man. The gadgets, in the case of technology, can be reached for and touched. But always when describing these early times, much speculation exists, and words like "first" should never be used. Instead of "first," "oldest known," or "earliest found," are more appropriate as we look backwards with less vision as time becomes more distant.

The sciences dealing with material, distinguishing between different kinds of substances, can be viewed as beginning with mining and extracting desired metals or even making a

desired metal as an alloy. The Sumerians extracted gold from dust by crushing rocks. The invention of a kiln (3500 B.C.) which could reach temperatures as high as 1100 degrees Celcius permitted the extracting of copper and tin from their ore, melting them to a refined liquid and mixing them, following secret recipes of oral tradition to produce bronze tools and other artifacts. These point to a sequence of metallic development, such as the addition of charcoal to alloys and the invention of bellows to increase the temperature in a kiln. The hotter temperatures paved the way for experience with alloys of gold, tin, silver, copper, and finally iron and steel. All of this may be true, starting with the Sumerians. In spite of the way most historians accept an evolutionary development of metallurgy, Tubal-Cain forged bronze and iron long before and surely passed that skill on to others.

Without having available descriptive words from ancient writings, one problem for the modern person is identifying what strange gadgets might have done. Such a gadget is a Sumerian boiling pot (FIGURE 1.1) that may have been a still, capable of separating substances through a vaporization condensation method. A circular pot with a near "V" cross section had an inner ledge about two thirds of the way to the top. Ingredients were placed in the bottom, heated and boiled. Vapors would condense on the curved, perhaps grooved cover, drip outward toward the sides of the pot, and collect in the inner ledge. Nearly unlimited speculation could be developed concerning the power of separation of substances such a tool would give.

3. SCIENCE OF ANCIENT BABYLON

Babylonian advances in mathematics, all before 1000 B.C., included solutions to the quadratic equation, hundreds of recipe solutions to what we now identify as the Pythagorean theorem, and cubic solutions of third power equations. The Babylonians had a number system based on sixty, the sexagesimal system. Leftovers from this system today are seen in our modern clock, with sixty seconds in a minute, sixty minutes in an hour, and four watches of six hours in a day. The circle with six groups of sixty degrees is also part of this sexagesimal connection.

Babylonian tables on astronomy from the dawn of writing confirm the existence of planetary observations, particularly the detailed risings and settings of planet Inanna (Venus) as far back as 3000 B.C. The record of solar and lunar eclipses from these times up to 747 B.C. were used by Ptolemy much later. The eighteen and nineteen year cycle of interplay between the sun and moon was well-known in this most distant age. The relationship of a whole number of moon months in a whole number of solar years became known as the Saronic eclipse cycle, since an eclipse can occur only when the moon, the earth, and the sun form a line in the cosmos which must be tied to this eighteen-nineteen year period. About 430 B.C. Meton rediscovered it, giving his name to this same phenomenon, calling it the Metonic cycle. Eclipses actually occur more frequently than once every eighteen years, but the time for each eclipse to reoccur is fixed to that eighteen-year period, and an eclipse only a few months later will reoccur in another eighteen years.

4. SCIENCE OF ANCIENT EGYPT

The ancient Egyptians should be recognized for two outstanding achievements, their advances in medicine and their development of a calendar. Oldest Egyptian writings reveal a vast understanding of herbs, spices, and drugs. Written diagnoses and

treatments exist for many illnesses and injuries. Surgery on the skull existed, and interintestinal tubes for feeding the very ill or those in a coma were used.

Tragically, quite separate from the medical doctors, the embalmers enjoyed a superior understanding of blood circulation and organ structure several thousand years before William Harvey gave such findings to modern science, but they never shared such knowledge. This advanced knowledge did no good in a strict caste society. Since the embalmers never talked to the doctors or surgeons, medicine and surgery in Egypt did not advance when it most likely could have. Science is like this. A lack of communication is responsible for the slow growth of scientific knowledge, and times of interdisciplinary exchanges give growth. In Egypt such exchanges did not occur.

The second great contribution of the Egyptians was the calendar. Their calendar of a 365 solar day year was the most accurate of all the ancient nations. It had three seasons; the first was the inundation; the second, the planting; and the third, the harvest. Some historians have tried to discredit this ancient people with such advanced knowledge, saying their year started with the flooding of the Nile river, a non-precise occurrence varying in the day of first occurrence, duration, and intensity. Nevertheless, the Egyptian calendar started precisely at the rising of Sothis (Sirius), which occurred in June during the second millennium B.C. (Today, due to the precession of the earth's axis, Sirius rises in August.) Each season followed with exactly twelve weeks. Each week was a decan, ten solar days long. Thus, the three seasons together gave thirty-six decan weeks or 360 days. Following the harvest season came half of a decan week or five festival days. No leap year was recorded, but it is easy to speculate that if Sirius became too far removed from the real inundation, a simple adjustment of the festival days could have kept things precise. Even without a leap year, the Egyptian calendar remained the most accurate for several thousand years.

Consider a strange thing. Moses, "educated in all the wisdom of the Egyptians" (Acts 7:22, NIV), was certainly steeped in the traditions of the decan week. Still, he writes a creation account of seven days and an Old Testament code of religious behavior based on those same seven days. Those separate ways of God's people, the Children of Israel, stand in testimony that God's creation is separate from man's measure. Also knowing the precision and accuracy of the Egyptian calendar and particularly Moses' understanding of that accuracy, we have no reasonable explanation that the days Moses wrote of could be anything other than normal days. Only with today's evolution, particularly its godless form of science, would one detract from the meaning of a day and try to explain that the time from one evening and morning to the next evening and morning is not a day.

Egyptian engineering and the science of climate control cannot be overlooked. Although it must have been during the declining years of Egypt when the Sahara Desert moved over the green land, a warring effort of survival through canal building and irrigation became a great contribution to knowledge. Much modern science now claims the Sahara once bloomed. Today the desert claims land twice as fast as irrigation can reclaim it. With a southern atmospheric jet stream nearer the Mediterranean than it is today, weather systems could have given the region a far different climate than most historians permit, but records of such weather were lost after God fought against the Pharaoh. Aristotle wrote of favorable climates, needed for a national power to grow, as lasting only a few centuries.

5. BEGINNINGS OF SCIENCE IN CHINA

In China a very different scientific tradition developed than what we are familiar with in

Western civilization. As we come into the twentieth century, that different world view from the East is important to science and cannot be overlooked or treated lightly. The eastern mind accepted opposites and contradictions as depicted in the diagram of yin and yang (FIGURE 1.2). A circle represents all. The white and black represent opposites, dividing all nature into two opposite equals. Yet nature that is white has within it a contradictory property that is black, and the nature that is black has within it a contradictory property that is white. The Chinese, then, accepted nature as it is, without concern to change it or to control it. They were not obsessed with solving human explanations of nature that seemed to contradict observations. The entire approach to nature was passive. If a river overflowed its banks, the Chinese simply moved out of the way rather than build dikes and levees.

Chinese science, tolerant of contradictions, did not advance as in the West until our century. Twentieth century science with particle and wave theory for energy, matter and antimatter existing side by side, particle annihilations and creations, its uncertainty and its probabilities of the quantum in a relativistic cosmos, can only be meditated upon in an Eastern sense.

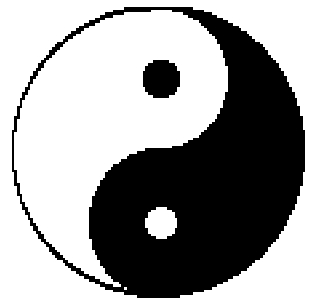


FIGURE 1.2 YIN AND YANG.

6. ANCIENT GLOBAL NAVIGATION

One of the greatest myths perpetuated in education is the idea that hardened, seasoned sailors were afraid to sail out of sight from land for fear of falling off a flat earth or, more reasonably, for fear of getting lost in the open sea, not being able to find land again. Perhaps some men might have had that fear, but not sailors! Let us make an analogy between airplane pilots and their relationship with the ground and between sailors and their supposed affinity to the shore. Today the average person does not have a sailor's experience with rope and sail, while many have had an experience with an airplane. When an airplane is far above the ground, it is in its safest mode. A pilot does not fly five hundred miles per hour only fifty feet above the ground for fear of losing the ground. He stays as far above the ground as possible. Only when landing at an airport does the pilot approach the ground. The same is true of a good sailor. He keeps his ship away from land until he nears a port of call. It is near land where reefs, hidden barriers, rocky coastlines, and pirates can easily destroy a ship. Near land it does not take much of an ill wind to run a ship aground. Out in the open sea most ships can ride out a storm. On the deck of a ship a sailor can only see twelve miles. Even in the so-called non-science days of early Greece, Homer has Odysseus navigate by stars out of sight from land. Clouds over an island extend visual distances for sailors, permitting easy island hopping. But the most convincing evidence for global navigation in very ancient times is the formation of the world itself. Sea currents and seasonal changes of global wind systems make long distance navigation possible.

A sail was raised long before a writing instrument. Sailing is a skill of high intellect, but it cannot be taught from a book. To this end George Sarton, a reliable author and scholar of history of science; Vilhjalmur Stefansson, author of UTIMA THULE and GREENLAND; and Anton Wilhelm Brogger, an archaeologist, all claim the Golden Age of ocean navigation existed from 3000 to 1500 B.C., before Phoenician navigation and before writing. To demonstrate the reality of this claim, Thor Heyerdahl sailed on a crude raft, the

"Kon-Tiki," built of Inca balsa logs from the rain forests in Peru. He sailed from Callao, Peru, April 28, 1947, traversed 4300 nautical miles of the open Pacific Ocean and arrived at Puka Puka and the Raroia Reef on August 7, 1947, in 101 days.

Heyerdahl again sailed on a papyrus reed boat (FIGURE 1.3), "Ra II," from Safi, Morocco, in North Africa, leaving May 17, 1970, and arrived at Bridgetown, Barbados, off the South American continent on July 12, 1970, sailing 3270 nautical miles across the Atlantic Ocean in fifty-seven days.

To complete a picture of a plausible dispersion of the nations by sea, Heyerdahl sailed in a boat made of Berdi reeds, "The Tigris." He sailed from the Tigris-Euphrates River to the Indus River and then to the Red Sea from November 11, 1977, to April 3, 1978, linking the cultures of Egypt, India, and Babylon with a journey of 4200 nautical miles in 143 days.

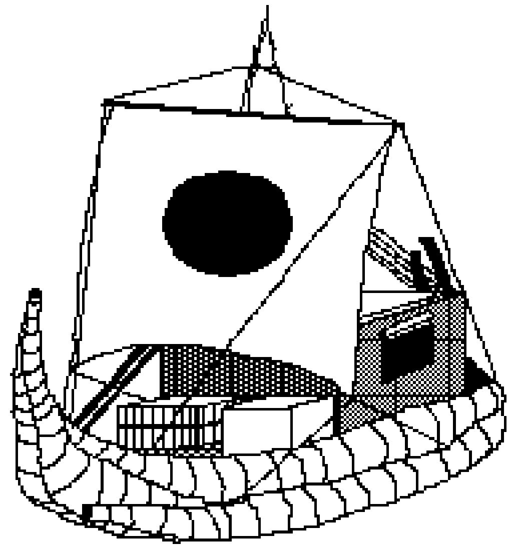


FIGURE 1.3 RA II

Many questions, of course, are unanswered and perhaps are even unanswerable. It is one thing, with a modern knowledge of the sea, to sail with a crude or very old style boat. Heyerdahl showed it could be done in our age. It is another thing to sail that sea without such knowledge. Still unanswered: Was it done by the ancients?

We would hasten to make the easy inference that after the Tower of Babel, the dispersion, encouraged by new languages, could have swiftly occurred by sea some time between 4000 B.C. and 3000 B.C. Yet historical time lines of the rise and fall of the many cultures around the world do not easily show such a sea dispersion. Heyerdahl denies any association with a Noahic Flood. Such is the way of intellect. We do know the people after the Flood refused to fill the earth. They had tremendous building skills. God scattered them by their own but different tongues.

7. OLDEST ASTRONOMY

Astronomy is the oldest discipline of science. Perhaps the awesomeness of the starry heavens and the cyclical motions of the planets captured the imagination of mankind and stimulated his explanatory wit. More likely, in the Garden of Eden Adam may have been told how to use the wonders of the heavens. Indeed, Moses wrote for the fourth day that the sun, moon, and stars were made to give light on the earth. These lights would control the day and the night. Certain lights would mark appointed signs God later spelled out in prophecy. Finally, Moses wrote that the lights were given for the calendar, which is exactly how mankind used them. "Let there be lights in the expanse of the sky to separate the day from the night, and let them serve as signs to mark seasons and days and years . . . ." (Genesis 1:14, NIV)

The sun marked the days; months were kept by the waxing and waning of the moon and by the prominent rising and setting of the sun in the twelve zodiac constellations. A change of the maximum solar elevation marked the seasons. A repeat of the zodiac order marked the years. Even long eras, such as a 2000 year span of time, are marked by the

precession of the zodiac. Finally, it is the firmament that shows God's handiwork. All mankind gazes upon the starry heavens and cannot help but praise Him.

Indeed, one function the sun, moon and stars played was to mark the inspired prophesied events. Miraculous motions of the sun and moon showed God as the defender of His people. A star announced Jesus' birth; the falling of the stars will announce the Great Judgment. In each case God's Word identified and explained the prophecy connected with these special astronomical events, which did not fulfill human interpretations.

Man's reason, denying God's Word and ultimately even denying the very existence of God, perverts all wisdom to pacify his own wickedness. In the last centuries of Babylon, studies of the stars were transformed into petty prophecies of wickedness. To show the fraud of modern astrology, which copies these errors, one need only remember that the zodiac signs correctly proclaimed the month and the new year, but only that. The start of a new year, the first sign of the zodiac, was the constellation in which the sun rose and set at the vernal equinox. About 2400 years ago that constellation was Aries. Today's astrologers still use Aries as the sign of April. Yet the sun has not risen or set in Aries in April for more than two thousand years. These days the sun has been rising and setting in Pisces and should very soon be rising and setting at the edge of Aquarius. Basically, the astrologers with their fraudulent science have not looked at the sky for an incredibly long time.

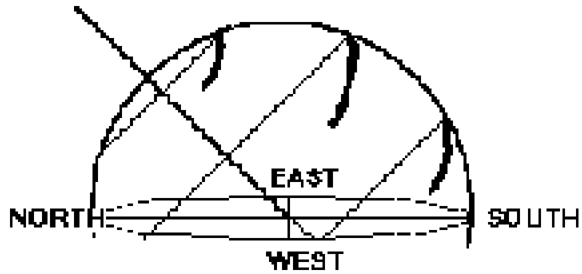


FIGURE 1.4 THE DOME OF THE HEAVENS

FIGURE 1.5 A PLANETARY RETROGRADE LOOP IN THE STAR CONSTELLATION SCORPIO.

Every ancient saw the entire dome of the heavens (FIGURE 1.4) turn over his head, with some stars rising in the east, while simultaneously other stars were setting in the west, as though all were connected in one great sphere of stars. Near the polar axis the stars rotated around the polar point. As seen today, stars south of Polaris (the North Star) move from east to west, while stars to the north and below Polaris, relative to an observer at a middle latitude, move in the same circular manner, but from west to east. All stars except seven were seen as moving together in a fixed position so that constellations, especially the zodiac constellations, could readily be identified, never changing their position relative to each other. The seven special stars (sun, moon, Venus, Jupiter, Saturn, Mars, and Mercury, in order of their maximum brightness) moved from west to east

at varying speeds with varying brightness, relative to the background of fixed stars. Some of these wandering stars even traced out loops in the sky (FIGURE 1.5). In spite of the crazy paths these planets (a Greek word for wanderer) followed, they remained only among the constellations of the zodiac. These motions have always been known.

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SEPARATE FROM HIS WORD

SCIENCE OF THE IONIANS: Separate from Homer, Chapter 2

1. THALES

Science as an explanation of nature cannot be studied historically until a written record survives with the scientific thoughts. The oldest known of these are from the Greek province of Ionia in Asia Minor. Greek traditions name seven philosophers as originators of science, and many of these may be legendary characters rather than real. Few of these lists are the same. The seven that have been chosen for this study all dwell on the beginning characteristics of science as a product of human thought. These seven all have a link to Ionia. Among them in this province we find Thales (624-545 B.C), the first of the legendary wise men of Greece, who may have been of Phoenician descent. He took residence in the city of Miletus, a chief sea port. Although his own writings do not exist, he is frequently quoted by men who lived after him; and through these later men, Herodotus, Plato, Aristotle, Seneca and others, we learn of Thales as a man of thought seeking explanations of nature separate from influences of the Greek gods.

Before and during Thales' lifetime, all Greeks believed that their lives were dominated by many gods and that a particular god caused every special and individual happening in nature. The Greeks had a mythical god for every natural phenomenon imaginable. Zeus was the cloud compeller and lord of the lightning flash. Poseidon was the earth shaker; Xanthus, the god of the river; and Hermes, the bringer of luck.

From its beginnings Greek science, through the mind and eyes of Thales, sought meaning in nature, predictability and cause without direction from the gods. Although the Christian may have good reason and even rejoice for this rejection of superstition and abandonment of the mythical gods, much of modern science and the philosophy behind evolution today provides an explanation separate from the description given of nature by the one true God, the Triune God of creation. When Thales is given credit for a timely and accurate prediction of a solar eclipse on the twenty-eighth day of May in 585 B.C., which darkened the battlefield of the Lydians and Persians, he made that prediction without giving credit to or without communication with the gods governing such phenomena. All scientists following Thales' methods at once found themselves persecuted for a lack of piety for believing in their own explanations as reasons higher than the gods.

Thales is recognized as the first of several scientists who had a connection to the city of Miletus. Miletus was the chief seaport on the west coast of Asia Minor on the Aegean Sea. This city supported Greek trade colonies on the Black Sea and also the Greek trade colony of Naucratis in the Nile Delta. The mighty navies of Greece, Phoenicia, and Egypt all filled the port of Miletus, bringing material wealth and knowledge from the entire world known to the sailor. The Anatolian Caravan Road, passing through Miletus, permitted the same exchange by land to all of Asia. This international city certainly provided Thales with many varying viewpoints, exchanges of ideas, and large quantities of disconnected facts--all so important to science.

With Persian expansionism threatening the Ionian cities from the east, Thales became very influential, encouraging them to unify their defensive efforts by forming a General Council in Teos. Perhaps his political success saved him from the persecution directed his way because of his scientific explanation of nature.

Thales had traveled extensively. His knowledge of mathematics is believed to have developed from Egypt. There he also heard of the solar eclipse of 603 B.C. It is unclear whether Thales learned of the saronic cycle, the whole number of lunar months fitting in a whole number of solar years; or if by his own mathematical methods, he calculated the eighteen year, eleven-day period, enabling his accurate prediction of the solar eclipse.

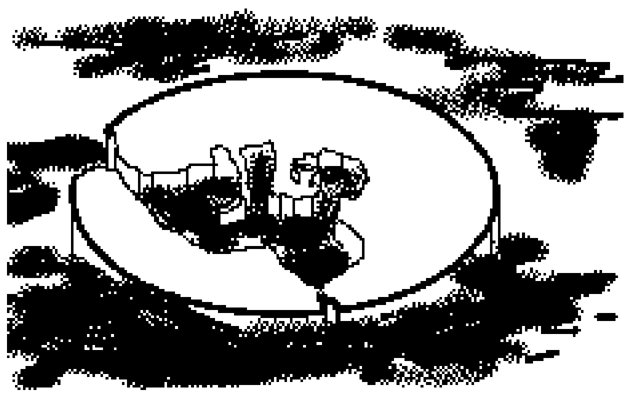


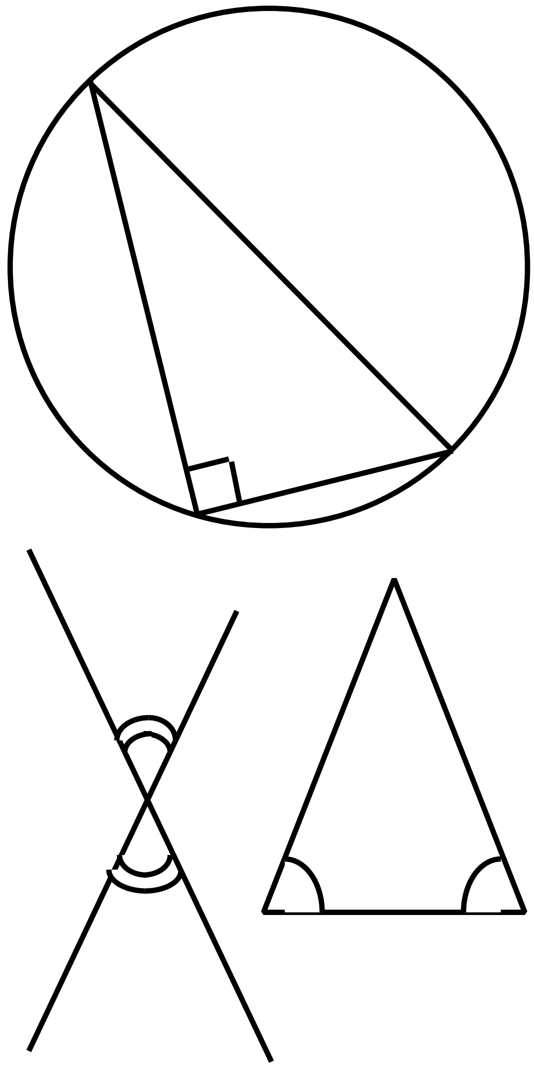
FIGURE 2.1 THALES' FLOATING EARTH

Thales taught that the earth was a flat disk or tambourine, about one third as thick as its diameter (FIGURE 2.1). The earth was suspended in space, surrounded by water, floating like a log in water, surrounded on all sides by the ocean. Three great anchor rings--the solar, the lunar, and the stellar rings--existed where the sky met the ocean. Two great arches or semi-circles rose from the anchor rings and formed a bow over the earth. The sun and moon traveled over the earth on these arches; but once they set, they traveled around the earth laterally along the anchor rings hidden under the horizon, moving horizontally until they reached the point of rising again. The stars rose as a hemisphere or half dome. As the stars set, they, too, moved horizontally around the earth along the anchor rings until they returned to their position of rising again. No motions were described as passing under the earth as a modern scientist might claim.

Two factors make Thales' prediction of the solar eclipse difficult to accept. The first problem is that when solar eclipses occur every eighteen years, the position on the earth where they are visible is rarely the same place, and unless the observer is very near such a place, it is doubtful if even a 90% eclipse would be detected. Secondly, in the view of Thales' astronomy, the concept of moon - sun - earth interplay did not exist.

Thales taught that water was the primary substance from which all other substances came. Life was generated through water. Earthquakes were a result of small motions of the earth floating in water. Water existed in a hidden form in the air, rose from the ocean, and fell from the sky as rain. Thales thus knew of what we today call the hydrological cycle. Tidal motion did not exist on the Mediterranean, making claims for water remaining constant very possible. Perhaps if Thales had seen the tides along the Atlantic coast of Spain or France, his science of water might have been different. Maybe not. The hydrological cycle is accepted today, even though a mechanism for making cloud drops grow into heavy rain defies discovery, and all attempts to reproduce rain under ideal conditions in a lab have failed at this writing. He taught that the flooding of the Nile was caused by Etesian winds, which blew strongly and steadily over the Mediterranean from the northwest in summer. This blocked the Nile from flowing out to sea and at the same time dried up the rivers in Greece.

FIGURE 2.2 GEOMETRIC FIGURES: TOP, A RIGHT TRIANGLE WITHIN A SEMICIRCLE; BOTTOM LEFT, EQUAL VERTICAL ANGLES; BOTTOM RIGHT, EQUAL BASE ANGLES OF AN ISOSCELES TRIANGLE.



Everything in Thales' scientific world was brought about by water. As water entered or left a body, it gave or took away life, power, and motion. Most Greeks insisted these things were caused only by the gods. Thales' picture of nature was quite logical and reasonable, fitting all the demands of observation. Water was seen as the vital ingredient of all things. Dry summers of Greece, in spite of moist winds off the Mediterranean, kept the Greeks actively seeking more water. The fight for survival against the increases of the desert invading Egypt and Persia was vividly known to Thales. Water was seen as truly life-giving. Water existed in most substances. Water was seen in its three phases in nature, an occurrence that is not so dominant for any other substance; and although ice, water, and steam were not known as the same substance, their interchanging form vividly

demonstrated water as the element involved with the formation of all other substances. The Greeks, a nation of sailors, could put away their gods for the science of water and still not be far away from Homer.

In mathematics Thales provided many true theorems for plane geometry, but it is impossible to know if he was first to formulate them or if he was simply passing on knowledge collected from his travels. He rightly claimed a circle is bisected by its diameter. Any triangle drawn with its points on the circumference of a circle and using the diameter of that circle for one of its sides must be a right triangle (top of FIGURE 2.2). The sum of all the angles of any triangle must be the sum of two right angles. The angles at the base of an isosceles triangle are equal (bottom right of FIGURE 2.2). Vertical angles, opposite angles formed by the intersection of any two straight lines, are always equal (bottom left of FIGURE 2.2). If corresponding angles of two triangles are all equal, then their corresponding sides are proportional. This theory was particularly useful for measuring the distance of a ship from shore and was used effectively by navies and shore defenders. Much later, by similar geometric proportions, distance between the earth and the planets would be measured. Tying together all of Thales' mathematical rules was the philosophical belief that what was true in the mathematical abstractions of points, lines, planes, triangles and perfect circles must also be true at the same time in nature. Nature would respond according to rules of mathematics. Thales claimed there were natural laws. This was the invention of modern science! Man by reason could search out these mathematical principles, knowing that nature would obey them. That gave mankind through reason the ability to predict, and that went beyond Homer.

For the Christian the birth of modern science, the invention of prediction, leads to an awesome fear of our Lord. The God of creation had given mankind a mind to correlate mathematical principles with events in nature and use them to predict. We should see in amazement that nature does follow the order comprehended in the mathematics. As a child of God, each of us must humbly cherish our reason as a great gift and train it and test it with His word and make it grow rightly guided by His word. Coming with the invention of prediction, permeating all science of man, is also the arrogant pride of man. "Ye shall be as God." What in faith can be a great gift, at the same time in pride can be a curse. Science, as a human invention in every age, is both.

2. ANAXIMANDER

Anaximander of Miletus (610 - 545 B.C.), a contemporary of Thales, a fellow citizen of the same city, is another man of near legendary quality. He, as Thales, attempted to explain nature independent of the Greek gods. Such information must again be drawn from many fragments of others. We are told Anaximander was a reinventor of the gnomon, a stick or pole planted vertically in the ground. I must say reinvented because it is incomprehensible that something as simple as a pole in the ground needed to be invented. The invention really is its use. From the gnomon an astronomer can determine the length of the year, the length of the day, the meridional position on earth, the real or local noon time, the solstices, the equinoxes, and the four major directions of north, south, east, and west. With the solstices and equinoxes the exact length of seasons could be determined.

In our time these items are easy to measure with the use of a gnomon when we believe we understand the motion of the earth and the heavens beyond us. But to become sensitive to the history of science, it is of paramount importance to try to understand these things from the point of view of the scientist in his time and place, in this case in Miletus 2500 years ago. Spend time with a flagpole during the day and night. Try to

determine these measurements of the calendar, but do so with the knowledge that the earth is a flat disc with three great anchor rings, the solar, lunar, and stellar rings of Thales. Then the first day of spring takes on a more difficult meaning. Also then science takes on a real and historical life of struggling human thought.

Anaximander drew the oldest known map of the world (FIGURE 2.3), which was later improved by Hecateus. He placed Greece in the center of the earth and followed Thales' water universe by placing the ocean as the outside boundary of all land masses. Anaximander, however, could not follow Thales' idea of a universe built on the primary substance or element of water. To Anaximander, earth or iron or any heavy substance could not be made from thinly flowing water. He did maintain the similar thought that all the universe was made from a simple primary substance. This substance was unlike any other substance known. He called this prime substance apeiron (a pi'ron). It was infinite in distribution, indefinite to measurement, undetermined to reason, and unexperienced by individuals. As an infinite substance, apeiron was in and of all substances. The entire universe was made of apeiron, which had an everlasting duration, turning through all boundless space. This substance gave endless rotation to all things, making the entire universe a spherical structure while rotating. Heaviest objects, such as rocks and earth, would fall, not to a bottom, but to a lowest position of fall, a kind of equilibrium position, although the concept of equilibrium was not used. Water was a little higher than the rocks and earth with fumes and vapors above the water.

The eternal circular motion was the source of universal power, an eternal power, a power of creation and destruction. Things came into being and ended by the eternal circular motion. Heavenly bodies came into existence as a circle of fire broke free from the fire of the universe, but these fires were encased in air and kept above the earth. At certain places, these heavenly bodies could be witnessed through pipe-like breathing holes. Occasionally, these holes became blocked and an eclipse occurred. The waxing and waning of the moon, through its monthly cycle, was brought about by this same clogging of these breathing holes. The sun's breathing hole was on a circle twenty-seven times larger than the earth; the moon's circle was eighteen times larger than the earth; and the stars followed circles still smaller, placing the stars lower than the moon.

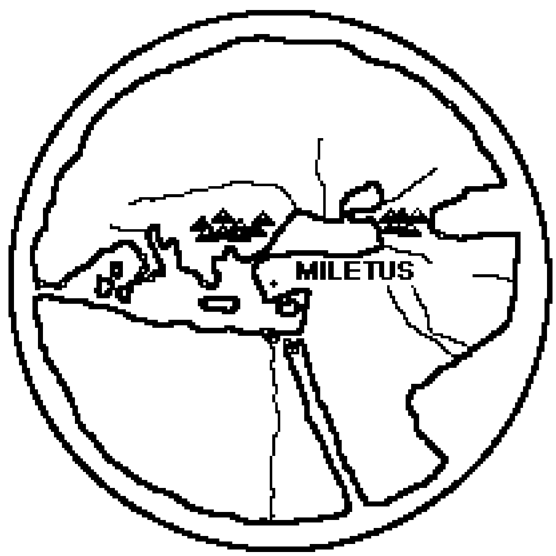


FIGURE 2.3 A SKETCH OF HECATEUS' MAP OF THE EARTH WITH MILETUS AT THE CENTER.

The entire picture of motion, according to Anaximander, was quite unified, explaining all things as developing from vaporous air in motion. Thunder, lightning, whirlwinds, typhoons, and the like were all due to the wind. At times the wind would be trapped in a cloud until it could break out. The break in the dark cloud was seen as lightning and the thunder as the sound of the break. From this concentrated, hard packed wind came rain to form the seas. The seas dried up by the sun forming dry land. The wind also moved the sun. From the water, in its wind drying state, animals were created. The first animals broke out of husks. Some found a suitable home on land and abandoned their husks.

Ultimately, mankind arose from the animals.

This oldest form of evolution, as reasoned by Anaximander, logically followed what was readily witnessed in Greece. Even today in that region of the world most insects come from marine larvae. Man, by this early Greek reason, had to come from animals. The human period of immaturity, the time from first formation until self-reliance, simply was too long for man to have been formed by the gods and left on his own as a suckling child before parents were invented.

Human evolution from animals fit a science developed to provide a reasonable base for knowledge separate from the gods. In the process, even before one generation of scientists could test their work, a contemporary of Thales had moved science to the point of eliminating from its thought all ideas of God as the Father of all creation and the uniqueness of the crown of God's creation, man, in the person of Adam.

3. ANAXIMENES

A third legendary scientific person, again from Miletus, Anaximenes, was born 570 B.C. The date of his death is questionable, but it was near 525 B.C. He also was a contemporary and fellow citizen of Thales and Anaximander. His impressions of nature departed from the other two over the understanding of the primary substance from which all things were made. Being more practical, Anaximenes insisted the primary substance must be knowable. He believed it to be air, a substance infinite in time, having no beginning and being indestructible without end.

Air gave cause to all things. Out of air all things were made as air took on different forms. In the finest or rarest form, air was observed as fire. When it became thicker, air was witnessed as the wind; still thicker, a cloud. The continuum of density followed to water, then to earth and finally stone. These changes of density were brought about by the air itself; but rarefactions or low density and low pressure were associated with heat, and compression or high density and high pressure were associated with cold. Observations confirmed it. An open mouth breathed out hot air while a semi-closed mouth, pressurized by blowing outward, gave cold air. Air gave life, mind, and love. The lack of air or air withheld ended in death. Air itself was living and immortal. In fact, the entire cosmos was living and breathing. Changes followed a "will" of the cosmos.

Anaximenes' work is the oldest known to claim that the stars rotated as a sphere or, at least, as a hemisphere. Planets were freely suspended in the air. However, none of the planets (including the sun and moon) and stars moved under the earth. In a strange manner they all rotated over the earth, but then the hemisphere spread out like the visor of a baseball cap (FIGURE 2.4); and the planets and stars rotated back to the eastward side while hidden by the coastal mountains, an edge of land at the outer limits of the earth.

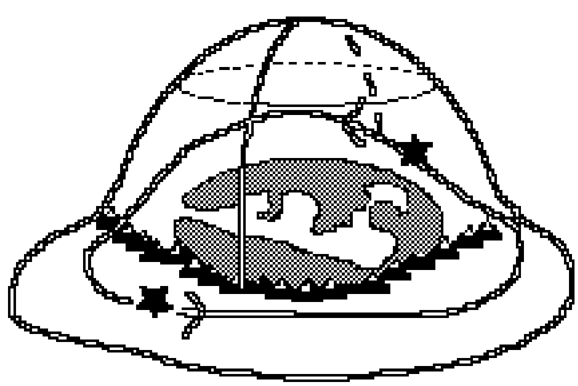


FIGURE 2.4 STELLAR MOTION ACCORDING TO ANAXIMENES.

4. NECO

King Neco, not from Miletus, not from Ionia, and not even a Greek, is important to Ionian science because he was King of Egypt at a time when the Ionian scientists looked to Egypt for that special touch of knowledge not acquired by staying at home. In distant Egypt King Neco reigned from 609 - 593 B.C. We know this king from our studies of the Bible where Neco is mentioned in 2 Kings 24:7, 2 Chronicles 35:20-26, and Jeremiah 46:1-12. Judah under King Josiah was caught between two growing super powers, Babylon to the north and east, and Egypt to the south and west.

It was during this time that the Bible had been forgotten by the people of Judah, but then suddenly found. I'll never forget the stunned sense of hopelessness I had at my first reading of these parts of the Old Testament while at sea under a foreign flag. Perhaps I had read them as required reading for a religion class, but that was just an assignment. When I read that during King Josiah's restoration of the temple at Jerusalem the high priest, Hilkiah, had found the scrolls of the Bible, obviously not in common use in the recent past, and had them read to King Josiah, I couldn't believe it. How could you lose the use of the Bible in church? But in such a time, when mankind searched out meaning to nature separate from God, the Bible had no meaning.

Thereafter, King Josiah restored the Holy Scriptures to his country. But the hope of religious reform for Judah was dashed when King Josiah was killed in battle defending his homeland as King Neco's army rolled across it to engage the Babylonians to the North. Even though many gave their lives to the Egyptians and soon many more were to give their lives to the Babylonians, those who had lost their Messiah had once again found Him when the Scriptures were returned to the people. The Egyptian King, Neco, was defeated at Carchemish on the Euphrates by Nebuchadnezzar and finally lost all to the Babylonians in their southward drive to Megiddo.

Practical science in Egypt was at a high point under King Neco. He had attempted to build a canal between the Red Sea and the Nile, a project that lost 120,000 lives and finally was dropped at the lobbying of the Goshen environmentalists, who feared the river delta would be flooded by salt water. These fears were confirmed through careful surveys showing the Red Sea was higher at the water surface than the Nile Delta. A century later Darius built the canal in spite of the salt pollution problem.

Under orders of King Neco, Phoenician ships sailed around Libya, the continent we call Africa, starting from Egypt through the Red Sea. In a season the expedition put to shore, planted crops, waited for harvest, and continued around Libya to record "in some amazement" that they "had the sun on their right hand," a statement quoted, but not believed by a Roman historian. After three years the Phoenician ship, under the Egyptian flag, sailed past the Pillars of Hercules from the west and returned home. This knowledge and skill, learned from global sailing expeditions was lost in the great wars between Egypt and Babylon and again Egypt and Persia. But even the expedition commanded by Neco may have been trying only to regain what King Solomon's navies once knew. Several centuries earlier they sailed away for three years at a time, returning with great wealth and spice. When global sea travel was again relearned by the Portuguese, three years gave Magellan enough time to sail around the world. The importance of the Neco expedition to the ancient scientists from Miletus is that it demonstrated their model of the world, land everywhere surrounded by the ocean.

5. HECATEUS

As the Persian empire swelled and the eastern provinces of Greece were taken up, the Ionians were pushed into the sea. Miletus was destroyed in 494 B.C. Born in Miletus before its fall, Hecateus (540 - 475 B.C.) was captured, but kept as a learned man by the Persians. He traveled extensively from the Pillars of Hercules to the Black Sea. With this experience he became known as the father of geography, improving the world map of Anaximander. His map showed the Nile River traversing the full length of Libya (the continent of Africa) with openings both in Egypt and on the far southern end into Oceanus. The flooding of the Nile each summer was explained as an influx of water from Oceanus.

Probably the greatest contribution Hecateus made to science was an attitude of skepticism toward the miraculous. Such an addition to thought processes was indeed very important in the century-long effort to overcome Greek mythology, which claimed the miracles of the gods governed every part of nature, with each particular god having his own special bag of tricks. Down through the ages, right down to our own time, it is important from a scientific point of view to seek out answers of nature from nature, and not from fanciful ideas leaning toward the wild or exotic side. In our own space-oriented age, a tendency exists to look to the marvelous happenings in the universe. For example, collisions with planets are used to explain the extinction of the dinosaurs; or, again, aliens visiting the earth artificially inseminated some apes to start the evolution of man. Other aliens supposedly constructed the pyramids.

Following Hecateus' example, it is better to confess ignorance than to turn to the miraculous. There was tremendous interest over the immense outpouring of energy from one volcano, Mt. St. Helens. This energy along with the scattering of dust was used to explain many unseasonable and abnormal events in the weather. A weather satellite revealed at the same time of the volcano eruption an even larger system of energy commonly called a typhoon. It raged in the Pacific for several weeks over many thousands of miles, changing the course of the Jet Stream that in turn altered the weather system of the entire northern hemisphere. Explanations of abnormal events in the northern hemisphere should be searched for in the common effects of the stronger and longer lasting typhoon rather than in the uncommon volcano. If an unknown is knowable, patience is needed in science to wait until enough studies reveal the answer. Skepticism is a good and necessary trait of a scientist.

For the Christian, however, such skepticism of the miraculous for all ages and all times runs counter to the revealed truths of our marvelous God, Who can perform miracles and has performed mighty miracles indeed. Daily He maintains the entire universe quite miraculously and quite independent of man's explanation of how He does it. An unyielding adherence to a Hecateus skepticism can lead to a rejection of those Biblical truths that are beyond scientific explanation. The miracles of Christ, His resurrection from the dead, and ultimately our own resurrection from the dead, are only a few, but indeed true miracles most important to our faith and very much beyond science. The miraculous must be a part of the nature mankind desires to study along with his science. God, in fact, answers prayer by both reasonable and unreasonable events.

6. CLEOSTRATUS

Cleostratus is the sixth of these founding scientists. With Persian pressure from the east, Thales fled to the island of Tenedos and may have had contact with Cleostratus before the death of the founder of science. The Greek style of legend likes to make such links.

Cleostratus mapped twelve constellations of the zodiac, and in particular, the paths of the seven recognized planets: sun, moon, Venus, Jupiter, Mars, Saturn, and Mercury. He carefully noted their deviation from the ecliptic. Although many of the motions in the heavens were known in a general way, no individual before Cleostratus was connected with such thoughts, and the emphasis for detail and accuracy is of paramount importance to the establishment of science.

7. XENOPHANES

The seventh individual was Xenophanes, again a Greek. He was raised in Ionia, but migrated westward rather than stay in Asia Minor under Cyrus. He can be called the first geologist. He taught an ancient mixture of the earth with the sea. After a time the earth and sea separated again, leaving the telltale signs of fossils behind, even on the highest mountains. Xenophanes showed abundant sea shells buried in the midst of the continent, far from the coast on high mountains. The print of an anchovy was observed in Paros; parts of all sorts of marine life were preserved as fossils in Malta. Xenophanes claimed these fossils were formed after all living things died and were embedded in mud. He further claimed all human beings perished during these times. Different from the previously mentioned Greek scientist, Xenophanes insisted on a god, a one and only god, from whom all motions came.

The Christian cannot help but see a meaningful interpretation of nature through the eyes of Xenophanes. A world controlled by the one and only true God is what we believe in. Likewise, Xenophanes, although claiming a deity by reason and giving a picture of global development by reason, describes a world destroyed by a flood. Its similarity to the account Moses gave of the flood in Noah's day is remarkable. We believe by faith in the one and only Triune God, Who made all things. We have also been given an independent ability to reason. Again and again these two great gifts, faith and reason, will be twisted by the human desire to be separate from God. Some men at times will march with blind faith apart from God's revealed Word. Some men at times will reject the revealed truth seen with faith and pridefully insist on reason alone. Both will take mankind away from the truth and all its benefits given by God in nature.

The invention of science by the Ionian Greeks was founded strongly on observation and reasonable interpretations. That is what makes people like Thales scientists. Religious inference, the miraculous, is rejected. Reason must be dominated by observation; the effects witnessed in nature must be the final test for acceptance. All seven scientists in this list appealed to observation for the verification of their ideas. This is the same ancient purpose for the modern-day laboratory, to verify by observation the causes in nature as explained by human beings.

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SEPARATE FROM HIS WORD

PYTHAGORAS AND THE PYTHAGOREANS: Number Gods, Chapter 3

The Pythagorean theorem, which states that the sum of the squares of the sides of a right triangle equals the square of the hypotenuse, is sometimes called the single most important discovery in science for all ages. That claim may rightfully be made, considering "a" squared + "b" squared = "h" squared was the first known formula merging together mathematics and science, a merger so strong and so long-lasting that unless a person is steeped in the integral calculus and differential equations, he cannot begin to comprehend the fluctuating environments of nature. With the Pythagorean theorem mathematics became the language of science. The scientist must be a mathematician. Because that is true, scientists of necessity become experts, far removed in their abstractions from the layman and his simpler understanding of nature.

Is this really so? Does nature respond to the formulas of men? Is the world God created truly mathematical? Is it mathematical even when He, as the Trinity, is beyond mathematics? A study of Pythagoras and the Pythagoreans will show the roots of this man-made approach to the study of nature with numbers.

1. THE LIFE OF PYTHAGORAS

Pythagoras was born on the island of Samos in the province of Ionia in 569 B.C. Details of a possible Phoenician ancestry are lost, but it was recorded that he wore an oriental turban. He insisted on wearing trousers like the Persians rather than the typical Greek robe. He grew a beard and let his hair long in Dorian fashion.

Samos, in these years, always felt threatened and turned to a strong leader, Polycrates. Greek patriotic pride, strongly supported by Polycrates, led such decidedly different persons as Pythagoras to flee Ionia and take refuge in Egypt in 538 B.C. Legend has Pythagoras choosing Egypt after encouragement from his teacher to go there to learn what was difficult for an old man to teach. It is legendary in the sense that Pythagoras' teacher was supposed to be Thales.

In Egypt Pythagoras studied in the temples and learned the surveying skills and the role of numbers in measurement. The Egyptian worship of the sun resulted in much knowledge of the motions in the heavens, which Pythagoras could selectively transfer to Greek thought. Temple life exposed him to the herbs, spices, and drugs of the Egyptians. One day in 525 B.C. Pythagoras' life suddenly changed when Persian soldiers marched along every road, into every town, and took charge of every public affair of Egypt. Cambyses' massive army found no match. Pythagoras was carried off to Babylon where he studied under the famous Magi, learned the secret rites of the magicians, and studied astrology.

After a time Pythagoras was allowed to leave Babylon and return to Samos; but after a short while at home, he left again, in part out of fear for the continuing threat of the Persians' overrunning Greek provinces in Asia Minor. A lack of personal freedom under Polycrates also contributed to Pythagoras' departure for the mainland. Uncomfortable in the heart of Greece and desiring a life of seclusion, he finally immigrated to a Greek colony in Italy, the province of Magna Graecia, in the settlement of Croton in 518 B.C. Here he

founded what became known as the Pythagorean Society.

This society, centered on Pythagoras' teachings, was an ancient communal society with each person serving the entire society and the society serving the individual. It was a secret society which never published any of its ideas, for each member was sworn to silence. At one time the Pythagorean Society numbered 2600 with 600 philosophers, or mathematicians by today's description, and more than 2000 akousmatics, the holders of common wisdom. The society involved its membership in purification rites that included water washings and drug-stimulated hallucinations designed to free the mind. New initiates were not allowed to speak on any subject of the society's concern for five years. Politically, the Pythagoreans were welcomed in the Greek colonies. They argued for a strong defense of the colonies against the fast growing Italian cities. On the Italian side, prejudice grew, culminating in persecutions against the Pythagoreans. For a long time the Italian wrath was vented by flinging many Pythagoreans over cliffs. Pythagoras himself may have come to this type of death. Other legends have him seeing a peaceful death at the age of ninety.

2. PYTHAGOREAN RELIGION AND REASON

The teachings of Pythagoras are difficult to comprehend with a modern mind. This difficulty also may be due to the Pythagoreans' oath of secrecy and their aversion to publish or keep records. We have only fragments, and those came from defectors, perhaps giving a wrong view of the society or its teacher. The philosophy thus preserved shows a mixture of mythical intuitive thought and reasoned explanations. It can be identified as rational in the sense that many of its mystic conclusions do not rely on a faith or a revealed religion. Pythagorean teachings are irrational in their demand for the unseen superseding and at times, opposing the visible. Three such ideas dominate: the inaudible music of the planetary spheres, the cosmos of divine numbers, and the concept that everything is created by the god number one.

These irrational teachings, in the worshiping sense, are far from our Lord's Word and truth and are the source for the modern trust that we can understand the environment around us by mathematics. The Christian link of our Lord's order in nature to mathematics must wait until the Reformation. But this Christian interpretation is only a Christian attempt to put the best construction upon Pythagorean "godlike" numbers. We have no Biblical encouragement to trust the Pythagorean theorem or Newton's formula for gravity or Einstein's energy and mass equivalence. Does our Lord govern the ordinances of the universe with equations? I don't know! I enjoyed finding some equations for the atmosphere. Yet in time, in a new generation, new equations will be found. The human quest goes on, excitingly unending. Equations of men, though exciting and aesthetically beautiful, will never satisfy the nature our Lord maintains. But the belief that numbers play a god-like role is from Pythagoras.

Pythagoras taught that numbers were eternal, divine, and permanent. Each of the numbers had a separate life and existence of its own, very independent of the minds of men. The numbers could communicate without audible sounds or visual signals in a sort of telepathic consciousness. From these living numbers come all matter in its constantly changing forms. Matter, created by numbers, was less than the divine number. Matter was mortal and perishable.

3. THE FIRST GOD OF PYTHAGORAS - THE ONE

In Pythagorean thought the numbers themselves had a hierarchy. The one was the beginning and end of all numbers and, therefore, the beginning and end of all things in the cosmos. The one was the source of all the odd numbers and all the even numbers. The one was not a number itself, since all numbers came from it. The one was the creator; as a creator the one was the source of limit; the one gave form. Geometrically, the one was embodied by a single point (FIGURE 3.1). A point had no dimensions, no weight, and no physical qualities, but a point was the beginning of structure, the beginning of shape and thus the beginning of function. The one took infinite matter in chaos and gave it symmetry. The cosmos through the power of the one showed order created from chaos. This cosmos was finite. Pythagoras saw the one as a ship whose created keel was the finite cosmos. The one then could be identified with Apollo, whose thunder clap was the symbol of the creation. Beyond the cosmos lay the infinite chaos. From the orderly cosmos flowed life as created from the one. Life expanded into the chaos, bringing an endless expansion to the creation. The one as the source of all life gave life to all things as witnessed in the motions caused by the loadstone and the amber stone. Living precious stones also grew in the ground and in other living rocks.

In this way, Pythagoras kept the mythical gods of Homer in the numbers and at the same time could develop mathematics in a rational sense, giving scientific reasons for happenings. He could remain pious before his number gods and predict nature independently of the gods. Of course, he and the many other Pythagoreans really believed in number gods ruling nature.

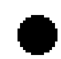

FIGURE 3.1 A POINT GIVES A POSITION WITHOUT DIMENSION.

4. THE TWO

In somewhat of a rebellious fashion, the two, though created by the one, took its existence unto itself. The two was very independent of the one. The two is opposite the one, with the one being masculine and the two being feminine. In her independence, the two became the source of change, the source of contrast, the source of opposition, and the initiator of rebellion. As the one created order, the two created disorder. As the one caused limits and created things from the finite cosmos, the two caused the infinite without limit. Both the one and the two were creators of all the numbers; therefore, they were not numbers. The one created all the odd numbers. The two created all the even numbers together with, but at the same time, independently of the one. In Pythagoras' scheme there existed a finite number of odd numbers but an infinite number of even numbers.

The two with the one gave a geometric line segment (FIGURE 3.2), the beginning of form in substance. The line segment shows changes of position from one point to another; thus, the two was responsible for the creation of motion. Motion is the essence of the universe being controlled and changed through opposite actions of the one and the two. Light came from the one; darkness came from the two. Light produced things hot, dry, and of low density. Darkness responded with cold, moist, and high density substances. Communication back and forth between the one and the two as well as between odds and evens of later created number-gods gave audible musical harmonies filling all of the universe.

From the one proceeded good and heavenly things, the most important being the formation of the eternal psyche. The psyche was a fire taking in both hot and cold air. The psyche of the aether of the universe was attracted to the earth, where it became imprisoned in a mortal body which was made by the two. More matter, being finite, was made by the many other odd numbers. This matter was restricted by time, which was infinite in duration, being created by the even numbers. Pythagoras thus defined time as marks of events created by the two and other even numbers. Each event was limited and separate from other events in an order set by the one who caused finite existence by leaving time itself eternal.

A doctrine of reincarnation followed. The Pythagoreans taught the infinite psyche was confined to finite bodies for a limited time. Then the psyche had to be alternately freed in death and bound in life. When a man died, his part of the psyche was free to dwell among the stars. Such a cycle of life, death, and new life displayed a reincarnation every 216 years.

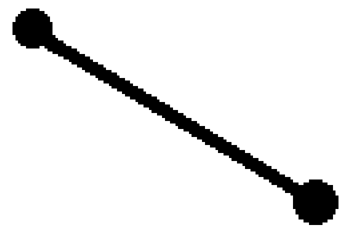

FIGURE 3.2 TWO POINTS DETERMINE A LINE.

As a last demonstration of the infinite nature of the two, Pythagoras pointed to the endless result of the square root of two. It equaled 1.414213562373... continuing to endless decimal places without forming a repetend. Several centuries later, a relearned understanding of irrational numbers by Archimedes would be viewed as a blow to certainty for rational ideas derived from numbers.

5. NUMBER THREE

Three is the first number. It was created by the one. It represents three dimensions but is witnessed only in two dimensions, with three points making a triangle of three line segments in a single well defined plane (FIGURE 3.3). It is three that directs the psyche to pervade all of the universe to animate all matter. The number three, then, is involved with the creation of all life, according to the Pythagoreans.

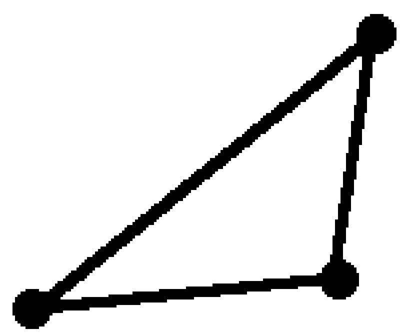

FIGURE 3.3 THREE POINTS DETERMINE A PLANE.

6. NUMBER FOUR

Four was the first even number and was created by the two in concert with the one. With the creation of four came the completion of three dimensions, the shapes of all things in space and of all matter. Four was the fulfillment of substance. Four points geometrically yielded a tetrahedron made of four triangles (FIGURE 3.4). This symbolized all matter and was in fact copied by many crystals found in the earth. Four became the second most important number, second only to the one. Pythagoras is quoted as saying, "I swear by him who has transmitted to our minds the sacred four, the roots and source of ever flowing nature." It is no accident that only four perfect solids existed for the Pythagoreans.

Those four solids were the tetrahedron, the cube, the octahedron, and the icosahedron (FIGURE 3.5). From these four come the four elements, earth, fire, air, and water, which form all other substances. Each element became associated with one of the solids. These were thought to be the only four perfect solids with perfect symmetry, and, therefore, there could be no more than four elements.

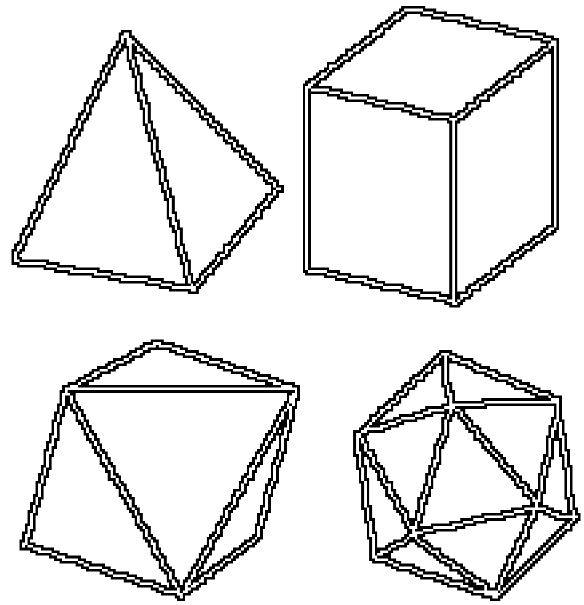

FIGURE 3.5 THE FOUR PYTHAGOREAN SOLIDS.

From god-number four comes the four chief musical harmonies in a diatonic scale. Music had always been very important to the Greeks, whose mythological musicians possessed supernatural power. The music of Orpheus charmed the gods of the nether world; the lyre of Amphion cleared rocks and stones from walk ways of ancient Thebes; Apollo set the mood for all the gods when he would play his lyre on Olympus.

Pythagoras eliminated these gods of music, and in their place the god-number four established the four harmonies to fill and control the universe, far overpowering all other melodies of mortals. The musical ratios controlled changing motions and positions of all things in the heavens. Each of the ten Pythagorean planets gave off piercing audible music according to the four harmonies. This music of the spheres was lost to any common listener. Pythagoras taught that the average person's hearing had become dull from continually hearing these harmonies, just as common smells rarely can be detected after the nasal senses have become accustomed to them. Among the many Pythagoreans, only Pythagoras could hear them because of the special training he claimed to have received from Abaris, a priest of Apollo from the distant planet called "counter earth."

Pythagoras purified the minds of his students with his music of four, copying the music of the spheres that he alone could hear. This music prepared the disciples of Pythagoras for the tasks of the day. Music prepared them for reflection in the evening. Music prepared them for rest and sleep. It was believed by purification of the body through washings, ritual acts, aromas, drugs, and music; that the psyche, bound to the mortal body, could return to the aether among the stars. Travel among the stars and communicating with the many races of people on the planets and especially in the Milky Way, Pythagoras claimed, could be achieved following the psyche in the purified, tenuous physical body. Astraios, a star child found under a pine tree by Mnesarchus, Pythagoras' father, had taught Pythagoras many of these things not otherwise known to humans by reason alone. Ultimately, the psyche would remain among the stars, absorbed by the musical harmonies of the stars when the physical body died, to be returned harmonically by reincarnation of the body with the psyche.

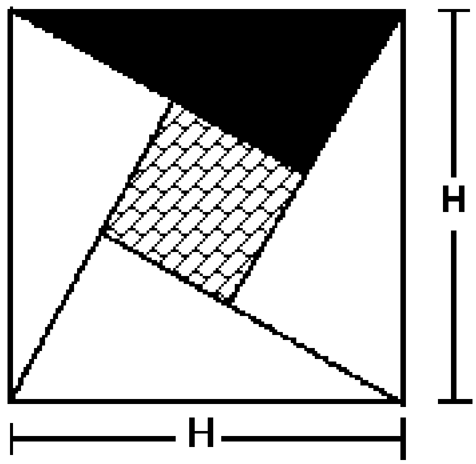

FIGURE 3.6 A SQUARE MADE BY THE HYPOTENUSE OF A RIGHT TRIANGLE.

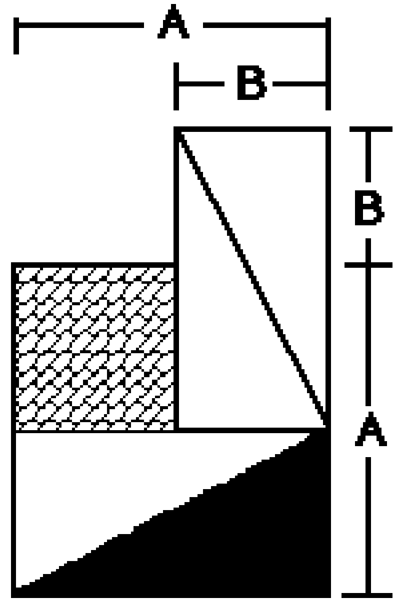

FIGURE 3.7 THE SAME AREA AS IN THE PREVIOUS FIGURE SHOWING
A^2 + B^2 = H^2.

Four led Pythagoras to the Pythagorean theorem we hold in such high regard today. The proof of the theorem is straightforward. He used four tiles all shaped as congruent right triangles. A large square area (FIGURE 3.6) was made, placing right triangular tiles in such a manner as to make a side of the large outer square equal to the length of the hypotenuse of one of the right triangles. A small empty square is left in the middle. A fifth tile can be made to represent that empty square area. If the long leg of a right triangle is equal to "a" and the short leg is equal to "b," then the length of a side of the small square must be (a-b). When the four right triangles (FIGURE 3.7) and the little square are rearranged, the entire area can be seen at once as the sum of the squares of the respective sides of the right triangle: hypotenuse squared = side "a" squared + side "b" squared.

Hundreds of recipes for this important mathematical relationship, especially in surveying, were known by the Babylonians. The famous 3-4-5 right triangle was known in Egypt. Pythagoras demonstrated a universal truth for all right triangles. More important to the Pythagoreans was that this formula came from the god four. The four points of the wind (north, south, east, and west) met at right angles. The vertical, as determined by falling objects, met the horizon at right angles. All these lines encompassed all of the universe from the limitless height to the endless horizon in all directions. These were brought together by four as god to form right angles and with substance as right triangles. Numbers, therefore, governed all of nature. If purified, man with the high mind of mathematics could grasp the interrelationships of numbers, the interrelationships of the gods. Man, like the gods, could know nature. Man could calculate what nature must do.

7. NUMBER FIVE

Counting with the Pythagorean number gods, we now come to the number five. This number is in the center of ten. Ten was the special god for a complete universe. Being half of ten, five had similar attributes as ten. Pythagorean proof existed in the pentagon, the chief shape for five. A perfect pentagon, five exact equal lengths as sides, can be constructed by loosely tying a wide ribbon into a simple knot, keeping all parts of the ribbon flat. A five sided star may be constructed, connecting every other obtuse corner of the pentagon. The image of the star shows the god five tying the entire cosmos with all the stars together in unity and order.

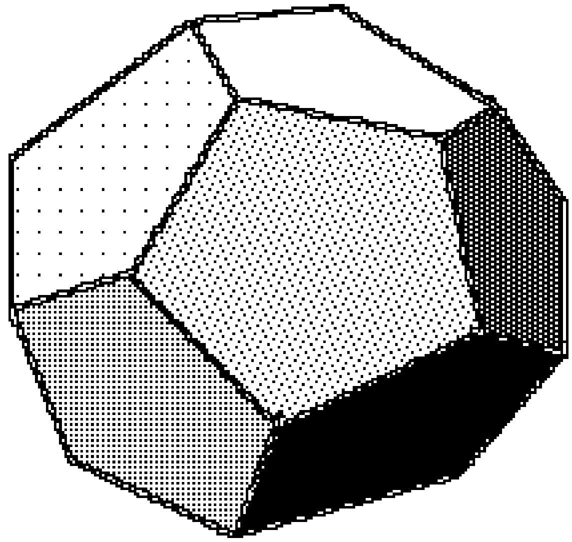

FIGURE 3.8 A DODECAHEDRON

Twelve congruent pentagons in three dimensions can form a fifth perfect solid, the dodecahedron (FIGURE 3.8). This solid remained the special secret of the Pythagorean Society, enabling them to enjoy a commanding understanding of all of nature. The discovery of the fifth perfect solid meant that there existed a fifth element. The star image in a pentagon signified a heavenly element. The universality of the fifth element came from the god number five. A five was an addition of two and three, a union of an odd number and an even number, bringing order and limits of structure to the infinite. Therefore, aether, made by the god number five, the fifth element, filled the universe, touching and moving the stars and all things in the heavens. Aether held and moved the wanderers, the planets; it was the holder and carrier of the psyche; it carried the music of the spheres. Aether brought life to and took life from all things.

Five also influenced the earth's structure. To the Pythagoreans the earth was a sphere with five geographical or climatic zones--the two polar zones, two temperate zones where people lived, and an uninhabitable equatorial zone.

8. NUMBER TEN

Five was always seen as half of ten and therefore ten itself. Likewise, four was thought to be the god ten in disguise, since 1 + 2 + 3 + 4 = 10. Counting to ten brings the list to completion. Ten itself means complete, for the god ten is a finisher. The fifth element, aether, the final element, together with the other four elements, could form all other substances, finishing a complete universe. This is what the god ten did. It finished a perfect universe. Unification, perfection, completeness are all part of ten. All are also part of five, and all are also part of four.

To the Pythagoreans any list that was complete had to be a list of ten. A complete ten was not just a choice of ten as the ten most wanted criminals or the top ten tunes. Ten meant ten, completeness in the strictly literal sense. The universe was complete with ten physical objects. The starry wanderers displayed a oneness, a unity, a musical song complete. The Pythagoreans believed there had to be ten planets to be complete, not

less and not more. In the search for these ten, over several centuries the Pythagoreans finally listed Jupiter, the sun, Saturn, Mars, Venus, Mercury, the moon, the sphere of stars, the earth, and counter earth.

Philolaus of Tarentum (480 - 400 B.C.), a full century after the leader Pythagoras had established the god numbers, recognized that if the earth is to be numbered among the wanderers--and it had to be so listed to reach the number ten--then the earth had to move and could not be in the center of the universe. The earth as one of the ten planets, including the sun and the sphere of stars, moved around an invisible fire. Aristarchus of Samos (310 - 230 B.C.), claiming to be a Pythagorean, extended the teachings of Philolaus but dropped the invisible fire and put the sun at the center. He also reasoned that the sight of the half moon displayed a right triangle between the moon, the earth, and the sun. Using similar triangles, Aristarchus calculated the relative distances, claiming the sun to be eighteen times more distant from the earth than the moon. (Today's astronomers use similar techniques and find the relative distances to be 1 to 390.)

9. AND COUNTING . . .

There exist many more numbers, and the Pythagoreans, continuing in their irrational yet rational vein, reasoned in favor of many gods. Nature and numbers have been inseparable ever since. When the understanding of nature grew beyond one type of mathematics, Isaac Newton, for example, shook off the constraints of algebra and geometry and invented fluxions or today's calculus to describe a cosmos that changed or fluctuated. New systems of mathematics replace old ones; and when they do, human understanding of nature is radically and simultaneously supplanted. Mathematics is the language of the sciences and to be a practitioner the scientist must speak mathematics better than the language he has learned from his mother. A people inadequately trained in these higher forms of mathematics simply cannot comprehend science as it explains nature. Today the gap between even a well read scholar and the scientist-mathematician is nearly unbridgeable. As a result, the scientist and his pronouncements appear god-like. They are believed and taught as certain as the number gods who are believed to have created them.

For as long as I live, I will never forget the immense excitement and awesome pride welling up within me while manipulating numbers to match processes in nature. A computer shortening calculations of several years to several minutes assembled numbers that matched almost exactly the wind spirals in nature never seen before. Numbers showed a nature not looked for before. Enthusiasm and false pride can be directed in this same Pythagorean way of understanding nature. A person can calculate the will of the number gods and believe that nature obeys.

Does the one and only true God, the Triune God, use formulas or numbers? He does not use numbers that we would worship numbers. He does not use numbers that man might be worshiped. If He uses numbers, He does so that His handiwork, both in nature and in the mind He gave to man, might be seen, so that we might worship Him.

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SEPARATE FROM HIS WORD

SCIENCE COMES TO THE GREEK TEMPLE: Anaxagoras, Chapter 4

With Anaxagoras science as a system of thought was brought to and taught in Athens, the center of Greek culture and political control, the very home of the gods on the Acropolis. This move for scientific thought was brought about by the continued expansion of the Persian Empire. The Persians had destroyed Miletus in 494 B.C., scattering the many disciples of the new system of thought, sending many to other Greek islands and to the mainland. The unrelenting drive of Darius of Persia continued to push the Greeks right out of Asia Minor across the Aegean Sea, finally to be halted on Athenian territory at Marathon in 490 B.C. In spite of the defeats, the Persians pressed hard on Ionia and the many Greek islands to the west and planned for another major invasion of conquest.

Anaxagoras was born during these times of turmoil and uncertainty in 488 B.C. Born an Ionian and taught in the scientific traditions at this time a century old, Anaxagoras immigrated to Athens. Xerxes, the new emperor of Persia, pressed hard against the Greeks but was stopped on the sea at Salamis in 480 B.C. in the finest naval tradition of Greece and then was pushed off the Aegean Sea. Greek city alliances, with Athens emerging as the leader, was responsible for this success against the Persians. The Athenian League grew in power, and Athens became a major city for politics, commerce, and the exchange of ideas. Anaxagoras brought science to Athens, where he was the first teacher of natural philosophy.

1. SCIENCE: AN ACT OF IMPIETY

Among the famous friends that surrounded Anaxagoras were the statesman Pericles and the poet Euripides. Anaxagoras was a contemporary of Socrates and at first was well received. Science was considered a new and higher philosophy in Athens. Some claim Anaxagoras enhanced the reputation of Pericles by sharing this new knowledge.

As with Thales, the teachings of Anaxagoras were an intense search for reasoned explanations for natural events other than the intervention of the gods of Homer. The natural philosophy of Anaxagoras was good. As science, it was very good to the eyes of men. Confidence grew with accurate prediction, and so did a feeling of certainty. But in Athens the establishment feared the new knowledge; and Anaxagoras, with his scientific explanations of nature, openly attacked the Athenian gods. For his boldness and impiety in rejecting the religion of the people of Athens he was arrested and tried. He was not pious before the gods, having rejected their role in nature. This was the offense worthy of death.

Pericles defended Anaxagoras at his trial and won an acquittal. Anaxagoras, however, was banished from Athens and was forced to return to Ionia. In another trial for a similar offense some thirty years later, Socrates was executed by being forced to drink hemlock. Athens rejected science, but Plato followed Socrates; and, in turn, Plato's student, Aristotle, followed the teachings of Anaxagoras. Athens had removed the impious from its midst, but science was there to stay.

We as Christians can applaud Anaxagoras for his rejection of the mythical gods, for in all

this the Christian knows the true God. As Christians, we should be equally struck by the impiety in science when it denies the Creator His place in nature. The sad truth is that the impiety of these Greek beginnings permeates all of science to our very day and keeps it separate from His Word.

What can be kept? What must be rejected? These are hard questions. The evil is so deep-rooted we would destroy the essence of science if we tried to rip out the bad. In Anaxagoras we see again the necessity to study these historical roots of science in order to understand science today.

Anaxagoras' natural philosophy is very modern in the sense that he believed in a unified science. He taught that there must be only a limited number of axioms upon which all explanations of nature can be built. He built his science around the fundamental questions and, just as a modern, he was not too concerned about finding the answers, but clung to the knowledge that they could be answered naturally without help from the gods.

The scientific brilliance of Anaxagoras, built on a century of Ionian tradition, is shown in his method. He exercised a high demand for passive observation, during which he left nature alone but watched her intently. At other times he found an active approach to observations beneficial. He would actively interfere with nature, attempting to alter the course of natural events to suit his understandings. These active observations are the core of scientific experiment. Braiding these observations and experiments with a strong logical analysis and drawing deductions from well reasoned axioms, Anaxagoras gave a complete unified picture of the physical universe.

2. PARTICLE VIEW OF MATTER

First of all, through Anaxagoras' eyes let us view a bright, red dyed fabric fading in the sun. The red color fades little by little to pink and then continues fading until all color has vanished. Sugar dissolves little by little continuously through a complete range of particle sizes until it disappears. Iron, when it rusts, passes through an infinite number of stages from metallic hardness to a powder softness. Most exciting to the intent eye is the variety of paths a burning log may cycle through. From the burning log Anaxagoras saw wood turn into fire. Fire changed into smoke. Smoke changed into a cloud. The cloud changed to rain. Rain fell to the ground and formed rivers which formed the ocean. In turn, the ocean tossed up mist that returned to the cloud. Rivers and the ocean formed earth, sand and salts as precipitates. The earth, in turn, changed into mists and stones. Mists from the earth rose to form clouds again, while stones gave fire to burn the log. The log also gave ashes which formed earth. Out of the earth came plants and animals. Plants gave food for animals. Plants grew into trees forming the log again.

All these observations showed a nature continually changing. In particular, they showed a nature changing from one form into another in a continuous cycle and returning to a familiar form which existed previously. The hydrological cycle from cloud to rain to river to ocean back to cloud again is one such cycle. Plants to logs to earth to plants again is another such cycle. These cycles for us lead obviously to the modern law of conservation of matter. Matter can neither be created nor destroyed, but can be transformed from one kind of matter into another kind.

For Anaxagoras, arguing from the specific items observed to formulate a major principle, such as the law of conservation of matter, would have been inadequate. A Greek philosopher needed much more. Anaxagoras started with a universally accepted truth, a

law of contradiction, that a proposition and its negation cannot be simultaneously valid. Struggling with what was real, Anaxagoras reasoned that substance is real and not nothing. Substance cannot exist simultaneously with nothing. Thus, argued Anaxagoras, matter, a real substance, cannot come from nothing. Matter cannot be created. The reverse follows immediately: matter cannot be destroyed. There cannot be a coming into being or a passing away of matter. Matter to Anaxagoras was eternal and could only be eternal. There was no beginning; there would be no end for matter. The gods of Homer were not needed for the material world and thus were rejected by Anaxagoras.

A Christian interpretation might be brought to bear on the law of conservation of matter. The Christian teacher might rightly point out that since all matter was created by our Lord, a human being can neither create nor destroy what God has made. Mankind is given all matter to manipulate and change for personal and societal benefit until the appointed Judgment Day. At the same time the Christian teacher must never forget that the origin of this oldest of scientific laws does indeed reject the Holy God of Creation and the final Judgment. This law, as developed, simply meant there never was a beginning. Anaxagoras, using reasonable logic fortified with observations of matter enduring cyclical transformations, boldly separated science from nature, which was purposefully, deliberately, and with love and care created out of nothing in six days as proclaimed in truth in Genesis. This separation at the start of science in the most fundamental precept makes a harmony between science of men and the Word of God impossible! This hard saying will not deny the Christian scientific knowledge. Instead, this hard saying will amplify in whom the Christian will put his trust.

With the acceptance of eternal matter, the science of Anaxagoras concentrated on changes brought about by the motion of particles. He believed all matter was made of particles infinitesimally small. Matter itself was considered continuous, which meant these particles could be subdivided without limit. Such subdivision, however, did not mean a division to a geometric point which had no dimensions. Each particle contained unchangeable qualitative parts. These qualities appeared as pairs of extremes, such as extreme coldness and extreme hotness. The addition of particles in varying proportions of extremes gave the observable macrosubstance its quality. In the case of hot and cold qualities, the proportional make-up of particles with extreme hotness and extreme coldness yielded the degree of heat witnessed by experience. For example, a pail of cold water contained more particles with cold qualities than hot qualities. As the pail of cold water warmed up, a particle exchange between the warm surroundings and the cold water occurred, changing the numerical makeup of particles in the water, ending with more particles with warm qualities than cold qualities.

The particle theory of Anaxagoras must not be related to any sort of theory of elements or atoms. According to his theory, each particle could be broken into many other particles. Each particle contained an uncountable number of qualitative parts, so that the particles were thought to be as complicated as the verifiable macrosubstances. Each of the qualitative parts were also complex. No quality could ever be isolated as pure. The qualities were considered infinite in number and kind.

The difference between life and death resided in these qualities within the particles. All particles contained some qualitative parts of life, so that a living substance was only different from dead substances because of the arrangement of the particles of the substances. An observable demonstration of this rearrangement was recognized when flour and wheat seeds were compared. The wheat seeds contained the essence of life for the living wheat plants. When seeds were ground into flour, the qualitative parts of them were rearranged in such a way that flour could not be considered living. Yet, when

flour-based foods were eaten, particles again would be rearranged and living tissue could grow.

The individual qualities in the microscopic world could not be any different from the observable qualities in the macroscopic world. This idea grew out of the short, but exceedingly complex question, "What really exists?" Anaxagoras gave the answer, "Things of the kind we perceive to be real really exist." This may sound foolishly simple, but to the Greek scientist the explanation of science had to be derivable from experience. Observations in every age are subject to interpretation, but the particular strength of the Greek invention of science was the insistence that the human senses could perceive the subtleties in nature as they really were. That perception is not so in our age. In the twentieth century the properties of the subatomic parts have no relationship to the perceived properties that are sensed.

3. UNIVERSAL MIND AS ORDER IN AN ETERNAL UNIVERSE

Anaxagoras did not permit the idea of creation of substances. Nevertheless, he had a beginning of order in the eternal universe. All matter contains qualitative particles of life. He said that all matter was once spread out into infinitesimal parts and mixed, so that nothing could be identified or seen as different. Then the living mind of the universe, similar to the mind of a person, not being substance, yet controlling all things of the substantive body, could cause rotational movement within the entire universe. This universal vortex formed the cosmos from chaos, giving motion, direction, and order to all things. The universal mind could be identified as a creator of order, but never as a creator of substance. Anaxagoras' universal mind was never a creator as our Creator described by the Holy Scriptures of the Bible Who brought forth substance from nothing by His Word. The existence of the universal mind could not be detected because it was not a substance, yet it could be comprehended by the minds of humans. Anaxagoras sought unified laws of the mind, but none were known to have been published and none were ever found.

Uniformity and symmetry are the marks of Anaxagoras' science. It is also the mark of modern science to explain all things in terms of the fewest laws the human mind needs to construct. His astronomy, centuries ahead of its time, displayed this symmetry and uniformity. He believed all the universe was made of the same substances as the earth. An explanation for things above the earth had to be the same for things on the earth. The sun was a mass of burning metal giving off so much light that it dominated the cosmos. The sun orbited the earth, moving both above the earth and below the earth. The moon was like the earth with mountains and plains. The light of the moon was reflected sun light, but no reasons were given for the phases of the moon. "The old moon in the new moon's arms," the faintly visible part of the moon compared to the very brilliant sliver of light of the new moon both were attributed to reflected light of the sun, but the dim light was left over from the previous month.

According to Anaxagoras, a universal property of the cosmos was spherical symmetry. The spherical symmetry originated from the circular motion initiated by the universal mind. Aether filled the spherical universe, holding the stars uniformly distributed both above the earth and below the earth. The sun, a sphere, gave off so much light that it hid the stars during the day; and when it moved to the other side of the non-spherical earth, the stars became visible in the dark. The Milky Way displayed the full density of the stars in the dark shadow of the earth, which was cast when the sun was under the earth. The stars away from the Milky Way appeared to be less bright and so few, only because of the sunshine reaching that part of the cosmos from underneath the earth. Comets to Anaxagoras were

clusters of planets, since the path taken by the comets went through the zodiac constellations the same way the planets did.

Aether, not as an element, but as an active substance uniformly distributed throughout the universe, played a central role in all phenomena on earth. Aether, a thin hot substance among the stars, possibly the main substance of the burning metallic sun, cooled as one might witness it descending to the earth and reaching mountaintops first. Then, continuing down to the desert, aether and air warmed again, coming toward the ground where the direct sun light and reflected light mixed to give the added heat. The middle atmospheric region was the coldest; and hail formed when warm water filled the air, rose, and froze in the clouds. At times aether fell in clumps, got caught in a cloud, and burned as it did on the sun. The result was lightning. The water in the cloud extinguished the fire with a loud sputtering burst of rolling thunder. Falling aether penetrated the earth through caves, porous rocks, and cracks in the dry ground. It became trapped after rains moistened the ground and sealed the cracks and the porous rocks. This trapped hot gaseous aether caused the ground to quake as it moved from place to place underground, seeking to return to the regions of the stars. At times the aether would become so concentrated that it would heat up and violently break through the earth's surface as a fiery volcano.

4. ANAXAGORAS' EXPERIMENTS

Anaxagoras' unified approach to science reaped great success by tying together many phenomena with only a few general laws, such as the symmetry of spheres and the universality of aether. With the boldness provided by his unified approach to science, he performed great public demonstrations. The most notable of these dealt with air. He claimed that air as a substance could resist a strong force. Anaxagoras demonstrated this by filling wine skins with air, sealing them, and then subjecting them to severe compression. Such skin balloons could hold up a lot of weight.

Anaxagoras, following the lead of Empedocles, a Greek pluralist teaching all things were made of four unchanging elements, used a water clock for another famous demonstration. A water clock was an open container with small holes at the bottom for the water to slowly drip out of, showing passage of time by the removal of water. Sealing the top of a water clock without water in it, he then submerged the clock in the water. He showed that the clock, when filled with air, would not permit water to enter the bottom time-keeping water holes. The obvious pressure of water could not overcome the subtle pressure of air. The reverse experiment also worked. A filled water clock, sealed on top, would not permit water to leave the container from the holes on the bottom. Any movement of any substance into or out of a container could occur only if the air in the otherwise empty container could move out of the way.

These experiments, interesting in themselves, were done as public demonstrations to show the belief of Anaxagoras that air was a substance of great elasticity and resistance, in spite of the common understanding that air was weightless. These properties of air were needed to foster his teaching that the earth was flat, in a continually near-falling position due to its great weight, but also continually being held up by air flowing under it as a leaf floating slowly down from a tree. Kites and sea gulls displayed a similar analogy. The earth, however, was very large and did not permit air to flow around it like the leaf. The earth did not move, but remained suspended as a weight upon an air-filled wineskin.

5. THE SENSES

The unity of Anaxagoras' science culminated in the explanation of the senses. To sense anything required a recognition of change, especially contrasting change. Opposites amplified the contrast, so that all senses worked through contrasting opposites. Particle properties played a most important role. The sense of touch was first and foremost. All other senses were derived from a form of touch. It is in touching that the properties of particles could be perceived. A chunk of ice, for example, stimulated the fingers of a hand by the cold qualities which dominated particles of the ice and came in contact with the hot particles that made up part of the fingers. The hot particles reacted to the cold particles and moved, causing a sensation in the finger as they made contact with the cold ice. Sensing hot worked in reverse. A hot iron was made of many particles containing the hot qualities, and they reacted with the the particles in the fingers that contained the cold qualities. Contrasting particles were thus moved, providing the stimulus to hotness. When a substance of equal hot and cold qualities in its particles came in contact with the fingers, both hot and cold qualities in the particles of the fingers would be moved, but the opposite qualities and the combined effect would not provide an adequate stimulus. In this manner a minor change of hotness would not be detected. Other qualities of the other particles, such as wet or dry, smooth or rough, would be perceived in the same manner, according to the dominant quantity of particles with a given quality to cause opposite contrasts, which could be detected as a stimulus.

The sense of taste worked exactly the same. Within the flesh of the tongue and mouth existed sweet and sour particles, which could be stimulated by particles with opposite qualities and thus be tasted. The sour particles in the mouth would be moved by contrasting sweet particles of food, stimulating the mouth in such a way as to detect the presence of sugar or honey in the food. Many other particles with different qualities would all aid in the complex differentiations that the sense of taste was capable of, but always in an opposite way.

The sense of sight was a touch where particles of color reflected in a contrasting way off the black pupils of the eyes. First of all, nothing could be seen other than what could be witnessed as reflected in the pupil. This conclusion required truly in-depth, exacting observations and interviewing of what one person could see and compare with what he, Anaxagoras, could see reflected in his client's pupils. All pupils of human eyes were black, permitting sensations from the maximum number of colors that would give a stimulus from a color particle impinging on the black particles. White light from snow caused the greatest opposite movement of particles, therefore stimulating the sensation of brightness which caused the person to squint. Humans could not see much at night, since dark colors did not contrast well with black pupils. Where black objects existed without contrasting background, a human could not perceive their presence at all, since no contrasting stimulus could be detected between black particles of the pupils and the black particles from the object.

6. OTHER BIOLOGICAL IDEAS OF ANAXAGORAS

A keen sense of observation led Anaxagoras to the conclusion that fish inhaled air from water through their gills. The rhythmic motion of gills on a fish were similar to his own rhythmic breathing motion. At the same time it must be recognized that such a conclusion is not possible without Anaxagoras' particle understanding of all matter. Only with the belief that air particles can be among water particles could such a function for gills be formulated.

To complete his view of biology, Anaxagoras believed plants breathed and responded to stimulus such as light. Plants built more tissue from food, sent their roots toward moisture, and opened and closed their flowers. These functions showed plants had minds like animals, like man, and like the mind of the universe. In the science of Anaxagoras, man was just another living thing, not different from plants or animals.

7. UNIFIED SCIENCE

A unified approach to science, such as that of Anaxagoras, can get an individual away from the truth our Lord reveals. God revealed what He did in His sacred Scriptures to show the truth. How else would we learn of our Savior, Jesus Christ? How else would we know God created all things? In science a Christian might see the unified approach given by Anaxagoras as a great gift when facing the unknown. A deep trust that nature changes and moves according to a few understandable principles is a lure to science for every race that practices science. Accurate prediction by applying explanations of a few principles believed to exist has given mankind immeasurable confidence of his understanding of nature. Only through history, over long periods of time, can the nebulous nature of these humanly invented principles be seen. A changed law of science does not tarnish the methods of science nor the hope of finding new or better principles that unify human understanding of nature. The excitement in pursuit of such new principles generates new scientists. Innovative, imaginative, and poetic people with unifying visions make new scientists and new laws of science.

What if such unifying principles are separate from His Word? That is why science must be taught in our Christian schools by Christian teachers. The teacher's Christian faith will show the lack of harmony between man's wisdom and God's truth. Teaching the youth keeps alive hope for a new understanding of nature with new principles of science solving new problems. Ideas of philosophers, scientists, teachers, and students will all change in time. God is changeless. His ways are true. Following Him is always the most exciting and unifying principle that He has given to us.

What about Anaxagoras? Priests of mythical gods drove him out of Athens because of his rejection of the gods. He failed to see that unifying principles work only if the God of creation in fact created such principles. We are convinced that God created such principles. He asked Job if he could comprehend the ordinances of heaven. Of course, Job could not. We cannot either. By knowing that God did create such order, we honor Him by searching for that order and have much to gain with such wisdom.

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SEPARATE FROM HIS WORD

THE GREEK ATOMISTS:
Leucippus and Democritus, Chapter 5

What is the stuff of matter? No age or race has known with certainty the answer to that question, and every system of thought on the subject in time has failed, even to our modern age. The struggle in striving for an understanding of that question is the special lure of science. The answers always require substances that can be seen by an understanding of things that cannot be seen.

1. THE SINGLE ELEMENT WORLD

We have seen the first attempts to explain the framework of substance by Thales, and the men who immediately followed him developed scientific traditions. Remember that Thales began with water. A single element, water, made all things. But water as the only primary element failed in the eyes of others. Anaximander explained all substances as derivable from an unknown element, apeiron, while Anaximenes turned to pure air as his primary substance. Historians have labeled them monists, teachers of the idea that a single substance could somehow form all other substances. Each in turn rejected the other's work because their common reason could not accept the capability of a soft or low density element being transformed into a hard or high density substance. How could water be transformed into iron? Although attempts were made to invent substances such as apeiron beyond the human experience in order to overcome some of these failures, the demand that things must behave in the same way as the senses could perceive them to behave always prevailed. For the monists the fundamental problem was reduced to the belief that if the substance representing the primary element displayed its properties in an unalterable state, then in reality no other substances made of that primary substance could change. In other words, if one thing could not change, then nothing could change.

2. MANY ELEMENTS

This crisis in thought gave way to the work of Empedocles, who took four of the most often suggested single elements of the monists' theories and merged them into a multiple element theory similar to the secret views of the Pythagoreans. Empedocles claimed all matter was made of earth, fire, air, and water. Historians classify men with a multiple element theory as pluralists.

Empedocles traveled extensively among the Greek provinces, but his home was his place of birth at Agrigentum (492 B.C.), a Greek colonial city on the southern coast of Sicily. This city was a center of Greek culture and attracted many Pythagoreans who were driven from Italy because of the growing self awareness of the Italian race that would soon be identified as Roman. The credit for the four element theory of matter is given to Empedocles, primarily because of his experimental demonstrations showing the existence of these elements in their pure state. Air was the most difficult to accept as an element due to its tasteless, odorless nature and the difficulty of witnessing in a common way its weight. We must remember wind many times was considered a different substance. Empedocles used a water clock called a clepsydra and a water tank to show the presence of air as a substance. Holding the top holes of the water clock closed with the many small holes at the bottom left open, he would submerge it under water. This way

Empedocles could show that no water could enter where the air occupied space. When the top holes of the clock were opened, enabling air to leave, the water was seen rapidly entering the lower holes.

The four element theory met failure also, in spite of the fact that more elements permitted a greater variety of change among substances witnessed in nature. Again the four known elements were too soft or of too low a density to explain the many hard and high density substances. In the human development of the understanding of matter, Anaxagoras followed other pluralists after Empedocles, creating the idea of particles with opposite qualities uniting for the large variety of witnessed properties of substances. Anaxagoras ultimately went to an infinite number of particles, each with an infinite number of qualities to give a seemingly infinite number of substances.

The full spectrum of ideas among the pluralists is shown from Empedocles' four elements to Anaxagoras' infinite number of qualities. The explanation of substances by the pluralists once more led to failure over this recurring theme. Witnessed symmetry in nature gives encouragement to the belief in a few primary entities in the structure of matter, such as a single element of a monist or a few elements of a pluralist. But when confronted with the diversification in nature, the few entities fail and give way to the many. The study of the history of science shows this with Anaxagoras' concept of the infinite qualities for the infinite particles. When the number of entities grows too large again, the symmetry calls once more for only a few.

In the twentieth century ninety-two elements and nearly a thousand isotopes gave way to three subatomic particles, the electron, the proton, and the neutron. Between A.D. 1945 and 1965 the list of subatomic particles grew. Nearly three hundred things such as mesons, muons, bylerons, neutrinos, leptons, and weightless photons were named. By the 1980's four quarks restored simple changeless symmetry as a new level of primary particles. Simple symmetry versus limitless diversity appears as an endless, but exciting pursuit in the understanding of the subtleties our Lord has created in nature.

Again and again the genius of one age with its laws of science becomes the nonsense of the next right through to our own age and beyond. That humility before the natural world our Lord has given us is what is most exciting for a Christian pursuing a scientific career. True Christian humility is a great gift that a child of God partaking in a scientific world full of false human pride can show and pass on to his scientific colleagues. Such Christian stability in the scientific world of elation and depression, discovery and failure, reward and persecution are gifts God gives the world through His children who know Who He is.

Is matter made of a few or many primary particles? This endlessly recurring problem can be traced to five important aspects of matter. First, nature displayed many opposites that appeared to continuously battle each other, hot and cold, sour and sweet, decay and growth. Second and more complicated than just opposites, there existed a seemingly unlimited variety in nature with an almost relentless change. Contradicting these observations, a unity, a preservation, an unalterable existed in many things as a third aspect of matter. The unchanging surface level of the Mediterranean Sea led to the conclusion from experience that an unalterable quantity of water existed. The march of the seasons, bringing change, nevertheless marked off a rhythmic unalterable calendar of events. Each successive offspring of living creatures resembled its parents and in turn produced seed for the next similar generation. The reasoning mind had the gift of classification and although each new age called for new ways to classify things in nature, the mere fact that they could implied a fourth aspect of nature, namely, that there truly existed separation and division in nature. Finally, a fifth aspect was noted: In life and death nature cried out for the witnessed permanence. Each new race of people had to

outfit an army for its defense. Many times this required that its leaders had to learn and relearn the same strategies when confronted with a near changeless geography. Empire after empire built on the foundation of the past and in turn fell in a similar manner. We do have a changeless God.

3. THE ATOMIC STRUCTURE OF MATTER

When the pluralists failed to explain the structure of matter struggling with the diversity in nature, the idea from the unalterable aspect of nature, the idea of a few entities, took its turn. Leucippus, the teacher, and Democritus, his student, both Greeks living about the fifth century B.C., invented the atomic theory as an answer. Not much is known about either man. Leucippus may have been born in Miletus about 475 B.C., but he wrote and taught his philosophy of nature in the city of Abdera in the province of Thrace. His atomic theory of matter was first written in 430 B.C. and entitled THE GREATER WORLD SYSTEM.

His atomic theory was incomplete and had many problems, but most were overcome by the explanations and writings of his devoted student Democritus. The younger man was born in Abdera in the eightieth olympiad which, was between 460 and 457 B.C. Out of humility and great respect for his teacher, Democritus titled his written work about atomic theory THE LESSER WORLD SYSTEM; but indeed it was far more detailed, and explanations were much more thought out, eliminating many previous problems. Actually, no part of these two important works has survived, but they were frequently quoted by many ancient writers. No attempt will be made to show the difference between the atomic theories of the two men. Essentially, from what is known they were the same, but Democritus understood and used the concept of a void, which Leucippus was reluctant to use, since many early critics rejected a void on the basis of thought that claimed an emptiness, a nothing, could not be comprehended and therefore could not exist for philosophical reasons.

The atomic theory of matter by Leucippus and Democritus began by searching for causes for witnessed phenomena of substances but restricted those causes to the substances themselves. Natural causes were desired, not supernatural causes. The concept that inanimate matter was lifeless, motionless, and without function unless acted on from the outside by a god-like power was rejected. The primary source of action, of motion, and of life with respect to substance must come from the substance itself. The cause for change must also come from within the substance changing. Again we witness at the inception of a major important doctrine of science a rejection of the gods, and the natural laws are developed from a totally materialistic view.

Leucippus and Democritus taught that the world was controlled immediately by the framework and structure of its own being. The law of conservation of matter was now firmly entrenched. The universe existed for all time. There was no beginning, and there never would be an end to matter. Nothing could be created out of non-existence. Nothing could be destroyed into non-existence. Leucippus and Democritus insisted that all changes and the consequences of those changes happened by necessity. Nothing happened by divine guidance. Chance happenings were also rejected. The material had a sub-structure to necessitate certain happenings so that they did not happen by chance or at random. At the same time, however, Leucippus and Democritus used the concept of chance to explain that things did not happen in nature with a preconceived design or plan.

Guiding such changes were atoms. All matter was constructed of indivisible particles and

the Greek word describing such a particle was "atom." Thus, there was a limit to smallness. One could subdivide a substance into smaller and smaller pieces until the smallest particle was left. That particle was an atom. Division beyond atomic particles was impossible. The eternal property of matter, its unity, its indivisibility, and its unalterability were due to its smallness and hardness. Atoms were so small that they could not decay or change. Atoms could not be divided or changed because they were so hard. The individual atoms gave matter its attributes of unity and permanence. The atoms' unalterable quality explained the presence of unalterable elements. At the same time an infinite number of kinds of atoms existed, and their rearrangement caused variety and change, not by design and not by random chance, but by the necessity that came from the atomic shape, size and motion.

Up to this point a great similarity existed between the structure of matter according to Anaxagoras and his qualitative particles and the atomic particles of Leucippus and Democritus. However, the indivisible nature of the atom raised the question of what is between the atoms. Here is where Democritus' explanations and revisions of the atomic theory of his teacher excelled and gave the atomic theory its lasting acceptance, although not without long hard-fought debates. The new idea was a void or an emptiness; nothing existed between the atoms. Elements were made predominantly of the same kind of atoms and a large quantity of nothing, of void, between the atoms. The concept of void was at first difficult to accept. Countless pages of explanation both pro and con during the next centuries fueled the debate over the existence of void. Arguments went like this, "If a void is nothing, then it cannot exist." "If a void is comprehensible, then it must exist." To Democritus, the concept of void was the single most important part of matter. Only with a void between the atoms could the atoms have room to move. Only with void between the atoms could atoms shift position, separate from each other, and reunite in a new way, giving the observed changes seen in nature. Void permitted the atoms to achieve all the things atomic theory claimed they could. A person could walk, breathe air in and out of his or her body, and throw things because emptiness exists between atoms. When one substance moved, there was a need for places to exist for other substances to go into in order to get out of the way. Those places, right down to the atomic level, must be void.

Void permitted motion of any kind. With a void there was no need of a cause for motion outside of the substance. Motion came from atoms within a body, with atoms continually moving. There never was a beginning to their motion, nor would there be an end to their motion. Motion, like matter itself, was eternal without beginning or end. Motion of material had no cause except from the material itself.

Collisions between atoms became very important to the formation and deformation of the many varied substances of the world. Two things could happen in collisions among atoms. Depending on the shape and size of the atoms colliding, at times the atoms became entangled. Even in their entanglements they kept moving. As the entanglement grew, it displayed compaction or condensations. Such condensations appeared to be a formation out of nothing; but since the atoms were so small, smaller than could be seen, the substance had always existed in a spread out form. The reverse occurred with collisions also. When impact was hard enough, again depending on the size and shape of the atoms entangled, the colliding atoms could recoil, causing other atoms to fly apart. The human senses could detect rarefaction and decay, which ultimately led to destruction. Creation, growth, decay, and destruction were all forms of atomic entanglements or separations. Everything visible and invisible was a product of atomic motions spacing themselves appropriately throughout a void, not by chance, not by a spiritual cause, and not by design. It was only by the necessity of the structure of the atoms themselves as they moved.

Scientific tests for atoms did not exist, and they were also not looked for. All observations of nature were explained by interpretations of atomic interplay. Explanation was considered adequate science. It is not much different today. The primary particle theories of today are tested by their ability to explain, not by the ability to isolate or witness such particles.

Leucippus and Democritus then expanded these ideas to a world system. Such is the way of science. The greater and more all-encompassing the phenomena that can be explained and united by a theory, the stronger the theory becomes and the stronger the confidence grows in the scientific explanations. The web of explanation, theory, and observation feeds back and forth, reinterpreting over and over, convincing all followers and excluding all unbelievers as non-scientific. Science has never been any different in this sense in any age for any race of people.

4. THE ATOMIC UNIVERSE

The world of Leucippus and Democritus was only one world among many. Their world was not unique. Their world did have a beginning and would have an end, but matter, made of eternally moving indivisible and unalterable atoms, always existed and played a role through collisions to form new worlds and cause the decay of old worlds.

A world, for them, had five stages of evolution. Void was limitless or infinite, and scattered throughout the great endless void were atoms of all shapes and sizes, each moving in its own way. Many atoms had formed many worlds and dissolved many worlds by their motion. A particular world started when many atoms, which were moving in a wide variety of ways, automatically began moving together in a large cosmic whirl. Each atom individually continued moving and colliding, thereby entangling each other and spreading out again. The whirl, once started, however, increased its speed and order. The formation of the cosmic whirl, consistent with atomic theory, was not started by any spiritual guidance or by design. A modern person might like to use the word chance, but the Greek scientist was very opposed to chance. Leucippus and Democritus insisted on the cosmic whirl beginning of necessity by the combined motions of the atoms in a certain region of the void. Because of the wide distribution of kinds of motions of atoms, no prediction of the start of unified orderliness among the atoms was possible. The necessity only referred to the idea that the atoms themselves collectively began the whirling motion. In modern evolution the word "chance" no longer causes trouble, and the explanations of the initial movements are essentially the same.

In the second stage of evolution for the world system through atomic motion, the great cosmic whirl separated large atoms from small atoms in a gravitational way. The large atoms moved down or inward, and the small atoms moved up or outward. The separation, however, was not a perfect separation and allowed for similar elements to exist both inward and outward as different entanglements later would give compounds.

In the third stage an outer membrane with considerable depth or thickness formed from the generally smaller atoms; and the larger atoms entangled inward, forming an inner solid sphere of many substances, adding structure to that world. Lands and seas were formed, and in our own world system these lands and seas formed the earth.

The fourth stage of atomic evolution of a world system gave more detail to the structure of the outer membrane. The atoms continued to entangle themselves by many collisions. These predominantly small atoms at first formed light moist substances scattered throughout the membrane at different levels. As the cosmic whirl picked up speed, the

substances solidified, dried out, and many burst into flames. These flaming chunks of matter in the outer membrane were the stars and the wandering stars or planets. The sun and moon were just larger bodies of material burning as they moved around the outer membrane. The Milky Way was a band of many stars also within the membrane and concentrated as a band by the atomic motions of the cosmic whirl.

In this atomic evolutionary model of our world system, it was rightly argued that the moon was the closest to the earth, the sun next, and the stars of the constellations the most distant. The wandering stars existed at many different levels or distances between the moon and the stars. The earth likewise turned according to the cosmic whirl. They argued against common observations in which the human senses saw the sun and moon travel across the sky more rapidly than the "fixed" stars; the cosmic whirl by its atomic motion gave an optical illusion. The stars really were moving the fastest. Coupling the stars' motion with the earth's spin, the apparent observable slower moving moon and sun really were moving in opposite directions. The beauty of this atomic astronomy is that it worked. Explanations and predictions have in every age confirmed theory.

Beyond the earth's outer membrane are other world systems with their outer membranes, stars, suns, milky ways, etc. In the last and final stage Leucippus and Democritus described the end of a world system by atomic motion. The atoms moved apart, disorganized the cosmic whirl, and all materials dissolved or evaporated. The atoms spread without orderly motion into all parts of the void. In this way each world system came to an end. The atoms spread out to regroup with other atoms, and the cycle would start all over again to form other world systems.

5. ATOMIC BIOLOGY

For the atomist life evolved from moist ground by arrangement and rearrangement of atoms through eternal motions and collisions. Worms offered the observational evidence for Leucippus and Democritus. That worms were made from moist ground was commonly accepted as fact because it was observed.

With atoms as the central active part in the development of living things, atoms also became most important to an understanding of the senses. Leucippus and Democritus, like Anaxagoras, identified the sense of touch or feel as the most important of the senses from which all other senses are derived. Feeling came from the interacting atoms and their collisions between the object felt and the atoms of the fingers. Physical contact, bringing atoms to atoms, was required for feeling.

Likewise, for tasting the atoms of food collided with the atoms in the mouth and tongue. The collisions of the atoms provided the typical sensations of taste, such as sweet, bitter, sour, or salty. However, the tastes themselves were subject to individual differences of interpretation. A sharp and distinctive taste came from sharp and rough edged atoms, but one individual might call such a sudden scraping from an atom bitter, and another might call it sour. Whatever the personal sensation, in each case, actual contact between atoms was necessary for taste.

Even sight required atomic contact, although intermediate atoms were active. An object, say a distant barn, would with its atoms impress an image on the atoms of the air in the likeness of the barn. This image would be transmitted from atom to atom in a relay through the air from the real barn to the observer's eye. The image would then be impressed by the air atoms through collisions onto the eye, and that impression would be seen. Color resulted from a mixture of atoms. White color was carried by smooth atoms that changed

from bright to dull by the orientation of the atoms in various slanting positions. Black was carried by rough angular atoms; red was identified with large spherical atoms, and green still another shape of atom. These four colors--white, black, green, and red--were primary colors limited to four distinct types of atoms. All other colors were brought about by a rearrangement and mixing concentrations of the color atoms.

Sounds and smells were carried by atoms and absorbed into the voids of all living creatures that could sense them. Since the ears and nose provided the largest openings to receive the atoms of sensing stimuli, the ears and the nose were most important for these senses, although the entire body played a role.

Thoughts of the mind were developed like the sensing stimuli. Objects thought about, as with sight, impressed an image on air and all other things, making contact with the mind. Air as well as many other things could carry such images by the motion of groups of atoms. These images would ultimately collide with atoms of the body of the individual doing the thinking.

The soul atoms, very small, smooth, spherical, and fiery, spread throughout the body, would be moved by colliding atoms in the form of the image. Thoughts were generated by changing positions of soul atoms. The thought of anger was brought about by intense collisions of images that increased the hotness of the fiery soul atoms and at such times overheated and in a repelling motion, would leave the body, reducing a person's thought capabilities. Homer wrote that Hector was out of his mind. Leucippus and Democritus could explain such an expression atomically. The atomic body of Hector had separated from the atoms of Hector's thoughts.

6. NEVER ENDING CHANGE

The atomic theory of Leucippus and Democritus did not last. As commonly occurs, scientists of the next generation found its weakness, and Greek atomic theory failed. Following this failure, the Epicureans developed atoms anew, and again they failed to satisfy the demands of nature. Particles or atoms historically fade in and out, and the concept of void went with them. Continuous matter without void was used in the intervening years. By A.D. 1800 John Dalton gave science a new atom held apart by forces, but the atoms of Dalton also failed. The twentieth century atom was full of much void in addition to the great percentage of void between the atoms. The twentieth century atoms are divisible in spite of their Greek name. The internal structure of the new atoms becomes more important than the atom itself. The problems remain the same. Atoms work well for simple phenomena, such as burning of a substance, dissolving, condensation, and even some physiological phenomena. In the complex realm of growth, aging, and thinking, atomic theory has always run into problems. The debate over design also never goes away. Democritus was emphatic on this point. To him atoms formed structure without design intended. Design is identified by the human mind everywhere. Stumbling into design necessitated by atomic structure and motion has always been an answer. Today apparent design seen by the mind in modern DNA exists not by a creator or designer but by atomic necessity. In every atomic age evolution becomes a dominant philosophy when design and cause for a phenomenon are from the material itself. At the core of every atom is the human thought of eternal matter, meaning no creation and no end. Every atom moves without an external cause, without God.

These two ancient properties of atoms, that the atoms are eternal and uncaused, must not be ignored by the Christian teacher. When a Christian teaches about atoms, if all that is done is to teach molecular structure or a periodic chart, Christian education does not

exist. If a Christian teaches about atoms and claims our Lord created them and guides their motion, if beauty and design are attributed to our Lord, that is only half of the teacher's work. The Bible is rather silent on the structure of matter. How do we know with certainty that atoms exist? We don't, but atomic theory works. If a teacher does not teach the philosophy behind the human invention of atoms when atoms are introduced into the child's lessons, that child may be easily turned from his faith by a teacher of higher learning, who will teach atoms as eternal and uncaused. As Christian teachers, we must teach God's wonders in all of nature. But the negative from the philosophy of man very much exists and must also be taught with the proper Christian warnings. Nothing is caused that God does not cause. God alone created and controls the stuff of matter.

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SEPARATE FROM HIS WORD

RELIGIOUS - SCIENTIFIC HARMONY: Plato, Chapter 6

When the Athenian navies had driven the Persians from the Aegean Sea, the coastal provinces of Asia Minor were restored to Greece, all with a strong alliance to Athens. Without fear from the Persians, all the Greeks prospered. The wealthy aristocratic class of Athens achieved its most dominant political power. In such a wealthy climate schools of philosophy flourished. Socrates' method of teaching by arriving at answers through questioning drew strong attention. The sciences of Anaxagoras and Democritus were examined but failed to receive acceptance in Athens because of their lack of respect for the Athenian gods.

As often happens in such comfortable times, Greece, as a nation of free cities and provinces united in alliance, turned on itself. Politically, the nation, once united against Persia, divided itself with allegiances to Sparta or Athens, and the bitter costly Peloponnesian Wars slowly destroyed a powerful democratic country. From 459 B.C. until the death of the Athenian leader, Pericles, the war between these great Greek rivals, Sparta and Athens, a war between warrior and statesman, could be kept some distance away from the cities without significant disruption to the way of life in Athens. After the death of Pericles, Athens could not find an adequate leader, and in its desperate demands of allegiance and taxation on the distant provinces, it soon lost its fellow Greek allies and faced the armies of Sparta alone. In 404 B.C. starving Athens, with its navy destroyed and its army brutally reduced in size, surrendered to Sparta.

Quickly Sparta gained control of Athens and all of its allied provinces. Envious hatred toward Sparta arose even more rapidly than it had toward Athens previously. War continued. In these troubled times, amidst the rubble, reconstruction of Athens and mistrust of the ruling authoritarian Spartans, the trial of Socrates in Athens occurred. Socrates was found guilty of impiety and of corrupting the youth. He was sentenced to death with a drink of hemlock required by a court order. With his death his disciples were scattered. One of those disciples was Plato, who was both an Athenian and an aristocrat.

1. PLATO'S LIFE

Plato was born in Athens in 428 B.C. He studied under Socrates for eight years right up until his master's execution in 399 B.C. Plato fled Athens after Socrates' death, hiding for a short time in Megara, and then traveled throughout Greece, to Egypt, to Italy, and to Sicily. During Plato's absence the bloodshed between Sparta and Athens continued. The old enemy, Persia, encouraged the hostilities by giving military aid to Sparta, assuring for itself a weak Athenian navy. When the Spartan navy grew, Persia aided the Athenian provinces. During this political intrigue Persia gained control again of all the Greek coastal provinces of Asia Minor. The king of Persia ultimately forced the Greek provinces to accept peace and an unassured end to the Peloponnesian wars, yielding to Persia all the Greek cities in Asia Minor. With much of Greece in ruin and Sparta weakly dominating after this imposed King's Peace of 387 B.C., Plato returned to Athens.

In a walled enclosure surrounding land once owned by an Athenian hero, Academos, Plato established his school of philosophy, which became known as the Academy. His school flourished continuously for more than nine centuries until A.D. 529. That year the Christian Emperor Justinian, ruler over the Eastern Roman Empire, ordered the Academy

closed because of its pagan and perverse teachings and scattered its teachers, letting most of them flee to Baghdad.

There were many schools in Athens, but Plato's dedication to the teaching of his philosophy is what made the Academy so famous, and in fact associated the name of his school with all scholarly activity. Plato has left a library of his own writing preserved through his academy. Many of these early works were imaginative dialogues between his teacher Socrates and another person. The second person was usually invented, and Socrates stood as a hidden spokesman for Plato's own thoughts. When Plato invented this fictitious scene, these dialogues were not transcriptions of recalled conversations, but a teaching technique using an authoritative name.

Little of Plato's personal life comes out in his writings, but he was a man of his time and nation. He was wealthy and an aristocrat used to a comfortable life with little to fear and lacking nothing in a material way. In his work THE REPUBLIC, he outlines an ideal state and its way of life. In that writing Plato shows as a matter-of-fact his homosexuality. He writes that the most desirable love is a sexual love between an adult male and a boy. In the Greek language such homosexuality cannot be missed. The Greek words are very clear and exact as to what Plato was saying. Many modern translators of Plato try to put the best construction on Plato's meaning of love. Both the Greek language and the Greek practice among the aristocratic rich clearly identify the tragic fact of homosexuality as an accepted way of life. In Plato's ideal republic the wealthy would establish a strong communal society, in which all the wealth and women would be shared by the men. The sexual sharing of the women would only be for the selective breeding of an elite youth. Sexual pleasure was usually homosexual. In another time or in another country, such writings would have been banned, but in the Greece of Plato's day a homosexual life style was quite common. (George Sarton, A HISTORY OF SCIENCE, Vol. I, Harvard University Press, 1952, pages 423-426)

This explains why Plato could write so freely about such perverted ideas as the ideal. But such perversions began with the worshiping of mythical gods and the worshiping of a science in which nature did its own thing. These forms of worship were essentially the same denial of the Creator. Such a denial or perversion of the Creator leads to self-destruction. "Therefore God gave them over in the sinful desires of their hearts to sexual impurity for the degrading of their bodies with one another." (Rom 1:24, NIV) Ultimately, the patience of our Lord runs out as He forms and guides the nations. "The outcry against Sodom and Gomorrah is so great and their sin so grievous that I will go down and see if what they have done is as bad as the outcry that has reached me." (Gen. 18:20, NIV)

2. PLATO SAW A CREATOR-GOD AS A MAKER OF ORDER

As far removed from God as the Greek traditions of both life style and science could take Plato, still his writings revealed the Scriptural truth that St. Paul wrote about to the Romans. "For since the creation of the world God's invisible qualities--his eternal power and divine nature--have been clearly seen, being understood from what has been made, so that men are without excuse." (Rom. 1:20, NIV) Plato rejected the godless science of former Greek scientists, claiming that a science without a god cannot show justice in nature. Plato strongly objected to the teachings of the atomists. Nature seen as a result of atomic motion Plato identified as soulless and fatalistic. He did not see atomic motion as motions of necessity. Instead, such motions not directed were by chance and without purpose. In spite of all the weakness of character and sins of life style, as a man of reason through his study of nature, he saw the cosmos as a work of a god. A god was needed to

take matter of a chaotic state and mold it into an image of an ideal model. This god had to be outside of nature with more power than nature. Plato's god over nature never could be manipulated by nature as many of the other Greek gods were. Plato reasoned that his god of the created order as seen in nature could override the order he created, but as a god of order he never did and never would. Along Greek social lines this god over nature was not seen as an aristocrat of leisure, but as a craftsman serving the community, not as a slave as most Greek craftsmen were, but as a free man of service.

For the Christian such a false god of reason is legalistic and can only rule man by condemnation. A condemnation of the godless understanding of nature is exactly what Plato wrote in LAWS for a statute against impiety. In spite of Plato's loss of his teacher Socrates because of the charge of impiety, Plato demanded that teaching with respect to science could not ignore a god. Teaching could not deny that the gods cared for men. If a person taught as the atomists, he could be charged and convicted of impiety. As a first offense that person could be held for five years in solitary confinement. If that person still had not recanted after five years, he could be executed.

The growth of scientific knowledge presented a dilemma to the Athenians. Science gave interesting and predictable results, yet did so by rejecting the existence of the gods. Plato found a harmonious solution by merging his thoughts on the concept of order with his thoughts on the existence of the gods. The order existing in nature was from a creator god, and this creator god did not deviate from the order he made. Recognizing order in nature from God helped the early Christian church to accept science in spite of some of its anti-religious beginnings and permitted much of the Platonic teachings to become part of the early Christian writings. We know that the Christian Triune God is the true God of creation and order. In Plato's time the leaders of Athens had always rejected the scientific philosophies. With a Platonic god creating the order seen in nature by science, scientific thought became acceptable.

3. PLATO'S DOCTRINE OF IDEAS

The single most important contribution of Plato to science was his doctrine of ideas, from which today we have the concept of ideal. Plato began with a strong mistrust of the human senses. To Plato all things perceived by the senses were subject to the personal emotions of each individual. Constancy was not even possible within one human being, for even within one person, the emotions were in a continual state of change. How true such a charge against the senses is! I remember from my own experience on an American expedition to the unexplored region of the high polar plateau of East Antarctica the feeling of severe cold at a temperature of thirty five degrees below zero Fahrenheit. Yet one year later the same still very cold temperature felt like a warm summer holiday after my senses had been hardened to the minus nineties, minus one hundreds and minus 120's. The sense of time can play tricks seeming to pass very rapidly when one is enjoying himself as opposed to the slow passing of time during less desirable work.

Plato trusted the mind above all things. Things observed by the senses could lead to knowledge, but things of the mind--abstractions, rigid definitions--were concrete, real, and above sensual knowledge. Here is where Plato's "idea" was very different from the modern ideal. To Plato the well-defined ideal cat in one's mind was more real than any living cat. In contrast to Plato, the modern zoologist might have in mind a certain species as an ideal cat, but always the real living cat today is more important to study. Nevertheless, today's ideal in science could not exist without Plato's forerunning "idea."

To Plato anything observed was a mere shadow of the idea within the mind. Intellectual

models of the way nature must be could be developed. General principles could give, by deductive reasoning, predictable results, which then might be observed or experienced in nature. If the senses did not see exactly what the mind constructed, emotion and fluctuations of the senses would be reasons for anomalies. Always ideas of the mind prevailed.

4. PLATO'S SCIENTIFIC METHOD

In the early written dialogues of Plato, usually between a student and Socrates, and usually invented, not a transcript of a true conversation, Plato set forth his trust in the questioning methods of his teacher. Plato's scientific method was set forth in such a dialogue between Meno and Socrates. A solution or answer to a problem seen in nature was assumed in the mind first before the question. Questions were then continually raised, challenging the original answer until either the answer prevailed as correct, or an obvious contradiction arose, demonstrating the answer to be wrong. This method of discovery is a second major contribution of Plato to modern science. Answers to problems must be known before the proper questions can be asked. To know what a proper sample is, the modern statistician must first know the ideal population before he can even test the sample. A scientist must demonstrate probable answers or results before funds will be made available to begin a scientific research project. In my own experience the National Science Foundation would not fund an expensive project requiring massive military logistical support in an isolated region of the world without promise of results. Answers are needed before questions. Ideas of the mind must prevail over experience. In reality, this Platonic method, together with ideas, provided a strong method of deductive reasoning, from the ideal general to the real specific. This was the only trustworthy method of discovery according to Aristotle, a later disciple of Plato.

Trouble in logic arises in Platonic thought. Plato claimed to be able to discover the facts about the universe by deducing their existence from the ideas of the cosmos. In Athens in the fourth century B.C., Plato claimed the cosmos had a soul. The proof lay in the idea that all living forms had souls. Plato claimed his cosmos was unique. His proof lay in his belief that the ideal model in the mind must be unique. The cosmos must be spherical because the ideal shape was a sphere. Plato himself invented the ideas in his mind. To deduce meaning into observations on the basis of preconceived ideas is circular reasoning. An error of logic does not mean that all of nature so explained is explained wrong, but it does mean all such explanations lack certainty. Throughout the history of science, that includes an immense number of explanations, theories, and laws of science.

Concerning the question of how close science can come to an explanation of nature, the whole process of abstraction of a necessity was circular. Once the mind determined how nature must be, the senses were well-trained in what to look for. Also of necessity, an abstract scientific approach to nature must involve error. There has not been an age where the best abstraction, the most detailed constructed model, or the best defined classification system has fit all the subtleties of nature. Such mismatches are always tolerated for the sake of the many achievements the concept of the ideal makes possible.

5. PLATO'S MOTION OF THE HEAVENS

The most successful of Plato's ideas for science was that all motions in the heavens could be described in terms of circles and spheres. The circle was considered the path for perfect movement. Since the sphere could be formed by a circle turned on its diameter, it was the perfect shape. For Plato the earth was such a perfect shape, a sphere. From the

spherical earth Plato viewed the stars as all part of one great sphere of stars which turned around the earth with an axis at a star situated over the earth's North Pole. Today that star is Polaris, the end of the handle of the Little Dipper. The spherical motion of the stars can readily be detected in the mid latitudes, such as at Athens. The sphere of stars makes one turn around the earth in slightly less time than one twenty-four-hour day. Today we measure the difference between one turn of the sphere of stars and a solar day as 3.94 minutes.

The comparative motions of the sun with respect to the apparent simple or perfect motion of the stars was a bit more difficult to determine. Plato saw the daily track of the sun as a summation of two perfect circular motions. The sun first followed a circular path called the "same," which was directly above the earth's equator and directly below the equator of the sphere of stars. All three of these circles (FIGURE 6.1)--the "same," the earth's equator, and the equator of the sphere of stars--were centered on the earth. The sun moved around the "same" daily from east to west but fell slightly behind the stars.

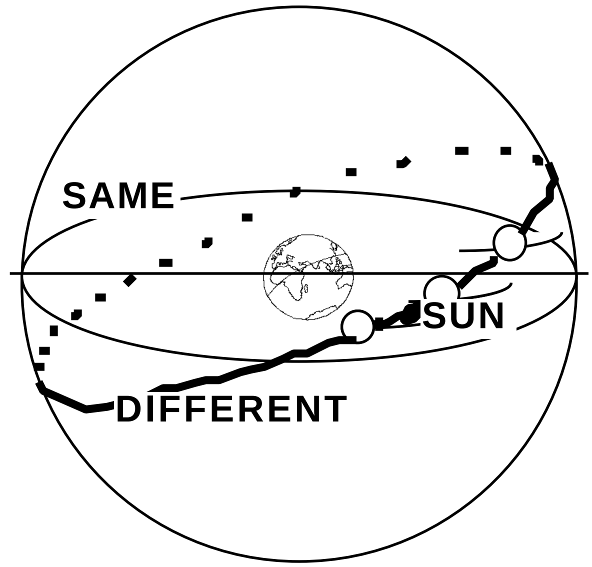

FIGURE 6.1 PLATO'S PERFECT CIRCLES, THE SAME AND THE DIFFERENT.

Simultaneously, in an additive way the sun moved slowly around the "different" which was its second perfect circular motion. The "different" was a circle sharing the same center in three dimensions. However, the plane of the "different" was at an angle of twenty three degrees to the plane of the "same." Thus, starting at the vernal equinox, the first day of spring, the sun was at the intersection of the "same" and the "different." It circled the "same," but after twenty four hours found itself higher above the plane of the "same" on the "different," slightly behind where it was the day before. In this manner the sun swept out a spiral path.

It is significant that the actual path of the sun is not a circle. Yet Plato, using ideas of the mind, explained its motion in terms of unobservable circles, and it worked for a while. Plato insisted that all the wanderers in the heavens could be explained in terms of circles and spheres, which were the ideal motions, the way of reality. Plato failed to explain the planetary motions in this manner, but he left that assignment for his students.

His student Eudoxus of Cnidus (409-356 B.C.) was a Greek scholar who studied with the Pythagoreans and also at Plato's Academy. He broke from the rigid adherence to ideas of the mind and today is considered a founder of observable cosmology. He developed the first major system for explaining planetary motion, following Plato's assignment of using only circles and spheres. He used a series of concentric spheres, all centered on a stationary spherical earth (FIGURE 6.2). Starting with the outermost sphere, it spun on its axis at a constant rate. A second sphere, in turn, was attached by its axis to the sphere above it at some nondescript position. If a planet were imbedded in this second from the outermost sphere, an observer on earth would see a twofold motion from the addition of

these two spheres. As more spheres were added, the motion of a planet at a particular position on a given sphere became more complex. Such a system could explain the retrograde loops traced in the sky by the wanderers, the planets. Eudoxus used up to twenty-seven such spheres to compensate for all of the motions of the seven planets. Another student of Plato's, Aristotle, also used Eudoxus' concentric spheres with much success. No system matched nature precisely.

Plato's failure in determining planetary motion does not display his successful dominance over scientific thought. For nearly two thousand years astronomers searched for circles and spheres that would explain the motion of the planets. By A.D. 1630 ellipses would replace the circles. It should be of interest to the teacher of science that when the change came, it could still be said that observable retrograde loops of the planets did not look like ellipses any more than they looked like circles.

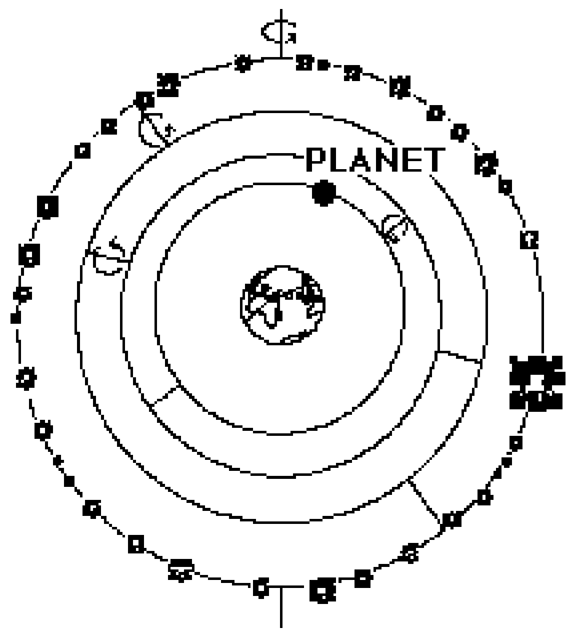

FIGURE 6.2 THE PLANETARY SPHERES ACCORDING TO EUDOXUS

6. PLATO'S WAR AGAINST ATOMS

Plato waged an intellectual war against the atomists and was successful at keeping such ideas out of Athens. He appealed to the strong patriotism for the Athenian gods. Plato argued that order can only come from a god, not from atoms themselves. The existence of justice was proof of the existence of the gods. Atomic philosophy professed a world by chance and was fatalistic. Most important for Plato was the idea that a person's mind was unique. Any individual person's mind was the only one like it in all the universe. No assemblage of atoms could produce a unique mind. Atoms could produce only randomness and never a special design, such as a mind. Systematic memory and thought required the most complex purposeful design, not by accident or at random. Plato reasoned such a design required a god. Also from Plato's ideal the ordered universe could be subjected to mathematical abstractions, to formulas of perfection, and that could not be a result of accidental atomic motion. Atomic theory required a maximum contrast of concentrated substance in the atoms and absolutely nothing, a void, between the atoms. For Plato a homogeneous nature was ideal. Matter had to be continuous with no limit to the division of the substance and no void. For Plato atoms could not exist!

7. PLATO'S CHEMISTRY

Plato taught, like the Pythagoreans, that in an ideal manner four, five, and ten were numbers meaning completeness. Matter in its ideal state existed in the form of five pure elements--earth, fire, air, water, and aether--a complete ideal list. The structure of matter included tiny corpuscles that could be rearranged, thus preserving the idea of elemental properties and permitting a transformation by moving the particles. No void existed. Each element was associated with a regular Pythagorean perfect solid. Aether was associated with the dodecahedron, fire with the tetrahedron, air with the octahedron, water with the icosahedron, and earth with the cube. The corpuscles visualized in Plato's mind actually arranged themselves into these perfect solids. Plato then used these solids in a mathematical way to show the mechanics of some simple transformations. Since pure water corpuscles formed icosahedrons, made of twenty equilateral triangles, and fire corpuscles formed tetrahedrons, made of four equilateral triangles, five parts of fire could be transformed into water. The reverse was also possible: one part of water could be transformed into five parts of fire. Other combinations existed. The twenty triangles of an icosahedron equaled the eight triangles of an octahedron and three groups of the four triangles of a tetrahedron. Therefore, one part of water could be transformed into one part of air and three parts of fire. One part of fire and two parts of air also could be transformed into water. Five parts of pure air could be transformed into two parts of water.

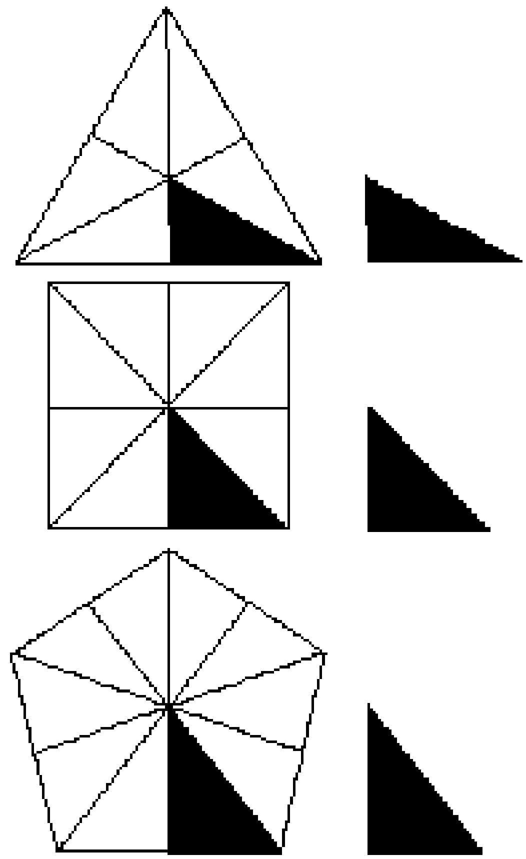

FIGURE 6.3 THE THREE DIFFERENT FACES OF THE PLATONIC SOLIDS WITH THEIR CORRESPONDING FORMING RIGHT TRIANGLES. NOTE THAT THESE FORMING RIGHT TRIANGLES CANNOT BE CONGRUENT.

Plato had a serious geometric problem transforming cubes or dodecahedrons into the other solids. A square side of a cube simply could not be divided into equilateral triangles (FIGURE 6.3). The same problem existed for the pentagon sides of a dodecahedron. Plato even broke down the regular polygon faces into isosceles triangles and then bisected them into right triangles. An equilateral triangle was formed by six right triangles; a square was formed by eight right triangles; and a pentagon was formed by ten right

triangles. However, the forming right triangles for their respective polygons never were congruent or similar. Plato had no way to transform earth into other forms of elemental matter. Aether also could not be transformed, but it could penetrate all substances, allowing for a change of consistency in materials.

These geometric problems were not as damaging to Platonic thought as a modern chemist might conclude. Metallic ores, for example, might be thought of as the element earth; but to Plato all molten metals were seen as liquids, and all liquids were transformations from water. The easy interchange between fire, air, and water adequately explained most changes of matter. Aether was always invisible, and the stuff of earth always was the inert ash left over from any other transformation process.

8. A VIEW OF PLATONIC THOUGHT

The Platonic explanation of matter was indeed an intriguing one that lent itself to the tests of a laboratory. Great gains might have been made for a science of continuous matter. Such tests never were made for Plato's ideas always overrode observations. Ideas of the mind, intellectual exercise, dominated; observations of the senses were never trusted. Over the entire spectrum of scientific thought, Plato's single most important contribution was, in fact, the ideal. Nature could be comprehended in the mind of man alone. It is abstract science, theoretical science, that pushed science forward, gave new ideas, new explanations and solved for a time countless problems. The ideal was always necessary for solutions, since it stripped away many intervening variables in nature, allowing the mind to concentrate on how nature must be in a simpler state, which never could be known any other way. This taking nature apart piece by piece and putting it back together again can only take place in the mind. Mere observation and laboratory procedures are too mixed with uncontrollable variables. Randomness, which Plato hated, appears to abound in the witness of the emotionally influenced senses. As the mind develops a more and more complex picture of nature, the hope always remains that some of the randomness will be understood and all would benefit.

These same ideas of Plato were singularly the greatest detriment to the growth of scientific thought. In trusting the mind over senses, much of nature was missed by ignoring extensive observation. Scientific thought under Plato and his Academy lacked experimental development. An arrogance prevailed that intellectual knowledge was more important than laboratory testing of ideas. For many centuries scholarship involved only quoting other scholars. In such an environment scientific knowledge did not grow. It remained trapped in the little minds of men and could not expand into the nature that the mind of God had designed.

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SEPARATE FROM HIS WORD

SCIENTIFIC METHOD AT THE LYCEUM: Aristotle, Chapter 7

The King's Peace, imposed on the Greeks by the Persians in an effort to stabilize the region from endless turmoil following the Peloponnesian Wars, offered no real peace, although enough stability returned to Athens to allow commercial and educational institutions to flourish. During these times in 367 B.C. Plato's Academy accepted its most influential student, Aristotle, who remained a member of the Academy for twenty years. Here he learned ideas and abstract methods from Plato while developing his own independent thoughts and methods of science. Later Aristotle taught these ideas and methods at his own school. And when he put them into writing, they influenced and even dominated scientific thought for more than 1500 years.

Many of the teachings from Aristotle's own school, the Lyceum, are worthy of learning and understanding even today. Those first twenty years of Aristotle's scholarship occurred during confused times of political unrest. The Persians, although not capable of conquering mainland Greece, fanned the flames of unrest by practicing political intrigue with secret support to both Sparta and Athens in an effort to keep both rivals from trusting each other. In this way Persia protected its western frontier. For awhile the Greek city of Thebes attempted to achieve leadership but fell to Sparta in the continual wars, further weakening and impoverishing all of Greece.

Methods of overcoming the many problems of Greece were debated with great oratory by two spokesmen, Isocrates and Demosthenes. Intercity rivalries were great. Isocrates lamented that Greeks would trust a foreigner, a Persian, before they would turn to a fellow Greek just because they lived in different cities. He warned against the collapse of the democracy and the moral degeneracy of the republic. Isocrates gave up on democracy, for he saw no hope in reuniting the warring Greek cities and provinces unless they might be united by a strong leader against a common enemy such as Persia.

Demosthenes, on the other hand, appealed to the heroics of the past, the individual strengths that together in a democracy gave a most desirable way of life and freedom worth sacrificing for, even dying for. He warned against a growing power to the north, Macedonia. Such a threat became reality with King Philip's ascendance to the throne in 359 B.C. While Isocrates saw King Philip as a savior for Greece, Demosthenes saw him as a traitor. Aristotle, born in a Greek Ionian colony on the peninsula of Chalcidice on the north shore of the Aegean sea, vocally supported Demosthenes' democratic party and objected to the growth of Macedonian power over his home province. Appeals by Demosthenes to patriotism and old victories at Marathon, Plataea, Salamis, and Artemisium fell flat in a democracy gone sour. Pride for a decadent race became a curse. As so frequently is witnessed in His story, without warning, and with incredible speed, God changed the political world and the way of life of its people. This was foretold by Daniel (Daniel 2: 27-45); and the kingdom of bronze was brought forth. The invention of the Macedonian phalanx, uniting cavalry and heavily armed foot soldiers in close deep ranks, row upon row upon row, all moving swiftly and in timed organization, changed the world. King Philip of Macedonia moved his phalanx over Greece, sweeping southward and inflicting peace by the sword on Athens in 346 B.C. The year before, Plato died. When the directorship of the Academy fell to Plato's nephew Speusippos and allegiance to the democratic party of Demosthenes became a liability, Aristotle left Athens.

Aristotle renewed an old friendship with Hermeias whom he met at the Academy.

Hermeias was a eunuch, a castrated man, who had become quite wealthy and influential as a money changer. Together they formed a school in Assus as a branch of the Academy. Here with a young student, Theophrastus, Aristotle began observational research by collecting living specimens of plants and animals from Lesbos. On behalf of Lesbos and other provinces near the Persian sphere, Hermeias made a political alliance with King Philip of Macedonia. Such an alliance cost Hermeias his life. He was crucified at the hands of the Persians asserting their power over the islands of the eastern shores of the Aegean Sea. Again scholars were scattered; and Aristotle, through his association with Hermeias, was asked by King Philip to tutor his son Alexander, then thirteen years old. The tutoring of Alexander the Great lasted only four years, and in 340 B.C. at the age of seventeen he became Regent of Macedonia while King Philip commanded the armies for the final conquest of Greece. After the Greeks lost the final battle under the trampling Macedonian phalanx in 338 B.C. at Chaeronea, King Philip established the Hellenic League with all the Greek provinces except Sparta under his control. King Philip was assassinated two years later, putting Alexander the Great on the throne.

Because of Aristotle, Alexander was sympathetic to Athenian wisdom. As an ambitious young ruler with the world's mightiest army, he unified Macedonia and Greece and immediately began a conquest across the northern coastline of the Aegean Sea to Troy and swept south, capturing all the Persian seaports and liberating all Greek provinces ruled for more than a century by the Persians. Alexander appealed to the historical roots glorified by Homer in the ILLIAD and the ODYSSEY and in this way won the hearts of the Greeks.

With his student on the throne, Aristotle could return to Athens in 335 B.C. in spite of its intense political divisions. Rather than have a membership at the Academy he established his own school at the gardens sacred to Apollon Lyceios (the wolf god), which he called the Lyceum. Aristotle's school was richly supported and protected by its great patron Alexander. At once the Lyceum became a rival to the Academy.

1. ARISTOTLE'S OBSERVABLE WORLD

Careful scrutiny of any man's work over his life time would show a change of thought in many areas of understanding, and the same is true of Aristotle. A study of his concepts and ideas from the beginning of his work at the Lyceum revealed an early belief opposed to his chief teacher, Plato. Aristotle's doctrine of actuality was best described in METAPHYSICS and called the "first philosophy." Aristotle rejected the Platonic belief that ideas were real and observations of the senses were inadequate and subject to emotions. The previous chapter defined Plato's ideas of the mind and showed how he believed such inventions of the mind were closer to reality than things observed. A mental definition and description of a tree, a fruit tree, was real to Plato while a plum tree from which one could pick a plum and eat it was only a shadow of the defined. To restate his views as interpretations of his student Aristotle, Plato mentally identified form in the abstract. The form, shape, and function of substance, of a particular fruit tree was that of a perfect fruit tree. The substance picked and eaten was only a shadowy part of what was real. Plum trees in a particular grove all contained flaws, broken or snarled branches, not perfect branches. The plums were of varying ripeness and sweetness; some were even rotten, according to the emotional senses, and were not ideal plums.

At the time Aristotle established the Lyceum, his train of thought had reached a point where he abandoned what he was taught by Plato and rejected form over matter. Aristotle believed, taught, and wrote that everything revealed by the senses truly existed. In other words, in contrast to Plato, Aristotle professed that the material observed by the

senses was real and therefore more important than the ideal. This doctrine of substance Aristotle called the "first philosophy." Non-ideal, twisted, cracked, old, or new branches were all real and really different from what could be classified or imagined by reason.

Aristotle saw Plato's ideal images as rigid and unalterable, not adequate for describing and explaining the natural world in a continual state of change. As an example, Aristotle would have accepted the observable fruit trees and their many departures from the ideal as the change in nature, showing the many different species of fruit. Professional orchard caretakers could really show changing plums through grafting of branches and pollinating the blossoms for the development of new seeds. Different plums, different shaped trees were to Aristotle's observational view of nature different species, and no mental demand could keep nature from changing. Oddly, this open view of nature by Aristotle, a rejection of the mentally fixed ideas of Plato, was turned around by church leaders a thousand years later. In the Middle Ages free observations separate from rigid idealization of Aristotelian thought were often rejected in order to preserve Aristotelian explanations of nature. Execution for heresy often followed for the observer. From the start Aristotle and his school placed observational science, a naturalist's view, over the abstract ideal.

2. CAUSES FOR PHENOMENA

In the scientific world of Aristotle, matter and the sense perception of it were real, and at first debate raged over the actual cause for a phenomenon. Aristotle claimed that four different causes, all acting simultaneously, were responsible for what was real. He began with matter as the first of the four causes, the MATERIAL cause. The material cause explained the "what" of the real substance which made up the phenomenon under study. If we use the example of a pyrex glass beaker from Corning, the sand and chemical additives along with the large quantities of heat used in the melting process of making glass would all be part of the material cause. The beaker could not exist or could never have been made without the fundamental materials. In spite of any thoughts or abstractions, a glass beaker cannot be unless the material for it is real and comprehended as real by the senses.

A second cause, not necessarily in a hierarchical order, was the FORMAL cause. The formal cause basically explained how a phenomenon occurred or what it did or what its shape was. In our modern example of a pyrex glass beaker from Corning, the formal cause would be its cylindrical shape with one end open and one end closed. But shape alone was not the end to understanding formal cause. The entire function of such a glass beaker, its ability to withstand extremely hot temperatures or extremely cold temperatures without breaking, its ability to permit a person to see what is inside the beaker by looking through the walls of the beaker, and the ability to hold liquids, solids, even highly corrosive substances are all part of the formal cause. Form as well as function are nearly inseparable qualities that describe the beaker-ness of the beaker as its formal cause. Much of Plato's abstract ideas can be seen in Aristotle's formal cause. The key difference remains, that to Aristotle the real material along with the real form and function of our individual beaker could yield important explanations while the abstract unobservable ideal form could not.

The third of Aristotle's four causes was the EFFICIENT cause. This cause answered the question, "Who made it?" Who was effective in causing the pyrex glass beaker to exist? For humanly manufactured things such a question is easy. The Corning Glass Company made the beaker in our example.

The fourth of Aristotle's causes was simply named the FINAL cause and for most

phenomena represented the completion of its understanding. The final cause explained the "why" of a phenomenon: why was our beaker made? For a complete answer, the motive of the maker is involved. What was the motive for Corning Glass Company to make the pyrex glass beaker? There could be several reasons and all would be part of the final cause. Good pyrex glass beakers are needed for the advancement of chemical research. Advancing such studies is a strong incentive for the production of beakers. Economic reasons, such as providing a profit for stock holders, wages for workers, and the expansion of the company, are also part of the motive. The desire to satisfy the consumer, the chemist, the teacher, the student, and their need for pyrex beakers is then also part of the final cause.

When we put all the material, formal, efficient, and final causes together, according to Aristotle, we have a complete understanding of the phenomenon. It might be said that we have a complete understanding of a particular pyrex beaker. Of course, each cause was explained in a very simple manner, penetrating only the surface of what causes can be understood. Much more could be said of each cause. Humbly it must be said that learning never comes to an end. Aristotle did not permit a person to believe understanding had begun until all four causes were understood at least in part.

The complete understanding of a humanly manufactured product, according to Aristotle's principles of causality, is somewhat easy. Materials were known because a human gathered them. Formal causes were known because a human designed the shape with a function in mind. The human was part of the manufacturing process, making efficient causes obvious. Motives of humans can generally be identified by other humans. It becomes more difficult, however, to identify four causes in the things of nature and thereby to claim understanding. Consider the plum tree. Material causes of the plum tree are the soil, the rain, the air, the wood, the leaves, and the fruit. The formal cause involves all the working mechanisms of the plum tree, its growth, the running of the sap, flowering blossoms, the formation and growth of the plums, and the growth of new trees from seeds or shoots of roots. After these causes the understanding of the plum tree in Aristotelian thought took a new turn.

In Aristotle's early works, his biological studies, the efficient cause for our plum tree was the plum tree itself. The plum tree provided its own seeds to produce other trees. The God of creation is not seen as part of the process of growth and reproduction. Aristotle's early logic took him farther from a natural knowledge of God when he looked for motives or final causes in nature. In both his biological works and in a later writing, PHYSICA, Aristotle claimed that a conscious purpose did not exist in nature. Nature did not deliberate. In this sense the search for a final cause for the plum tree could not be found in a personal god or in a personified nature. Instead, Aristotle used potentiality as a final cause. A potential existed in the seed of every plum. Every plum had the potential of being a plum tree and of bringing forth more plums. This was a final cause in nature. Final causes in nature served potentiality. A child has the potential to become an adult; a colt, a horse; and a seed, a tree. Final causes of nature served nature itself.

Modern evolution follows similar logic. There is no deliberate preplanned direction to the evolutionary process. Still, if a final cause is pursued, it is expressed as a fulfillment of potentiality from nature itself. A modern apologist for Aristotle, Mortimer Adler, sees efficient and final causes combined in nature as one, with nature itself directing the evolution by potentiality.

In Aristotle's later work on astronomy dealing with motion, he found difficulty explaining efficient and final causes in non-living nature. All experience showed a cause connected to each witnessed motion. In the heavens above the moon, motions were seen as

caused by concentric spheres, each with an independent axis. The motion of each sphere was caused by the sphere above. What caused the outermost sphere to move? The demand for an efficient cause ultimately required a primary mover that did not move in order to move the sphere of stars beneath it. According to Aristotle, something must always exist to initiate motion and to maintain motion. In order to do that, the primary mover, a god, was the efficient cause giving change and thus potential motion to all spheres below. Aristotle's teaching of potentiality required the primary mover to be unchanged without a resulting potential itself. His doctrine of actuality insisted that the primary mover actually existed. Such a true existence gave the final cause of motion under the direction of the primary mover as his desire and love. Actuality required, at least in thought, that a living god with a domain of the entire universe existed and that existence was fulfilled by motives, final causes, for all motion of all the universe.

3. COMMENTARY ON ARISTOTLE'S CAUSES

In pure reason, are Aristotle's four causes the only causes? Are there more causes? Could there be fewer causes? Answers to these questions must be left for another author. A Christian certainly should see the existence of the four causes in nature but see them quite differently than Aristotle. The materials for our plum tree we have chosen to study are all provided by our Lord. The form and working function of that plum tree have all been designed with purpose by Him. He gave nature its direction. He gave it potentiality. He maintains all the weather, soil, and mechanisms for the growing of a tree from its seed to its fruit and new seeds. The living Triune God is the efficient cause of our plum tree, all other trees, and everything in nature. He has His motives for causing all these things. His motives are the final causes. God's motives certainly include doing His own will and doing all things out of love for each and every one of us. However, all of our Lord's motives as final causes may indeed escape our limited reason. If we have buried a loved one, fought in a brutal war, witnessed widespread starvation, suffered failure or physical pain, we do not so readily identify our Lord's purposeful, careful, merciful guidance as final causes in the world that affects us. We have the entire book of Job in which he writes of similar problems with identifying and understanding final causes governing his life. Job, although never told of God's motives, was lovingly led to a humble confession of trust in his Lord for "things too wonderful for me to know" (Job 42:3, NIV). As Christians, we are not expected to know final causes for all things. We do, by faith, know efficient causes for all things as they rest in our Lord's hands. Knowing He is our efficient cause is our strength and confidence to trust Him for all else. Not always knowing final causes keeps us humble before our Maker.

In the open market place of modern science, efficient and final causes are rarely looked for. Where a particular scientist may have a philosophical interest, efficient and final causes are merged together, emphasizing the potentiality of nature as Aristotle did in his early work. In this way the methods of science do not look to the Triune God of creation. Isaac Newton, at the end of the seventeenth century, rejected searches for efficient and final causes when he wrote publicly, "I frame no hypothesis," while in private letters he confessed a unitarian god over providence. It could be the desire to keep science out of religious debate and sectarian conflicts that is responsible for modern science's ruling out most explanations of efficient and final causes during these last several centuries. It could be the deep rooted traditions from Thales and his contemporaries desiring to eliminate God from explanations of nature. More likely, the wicked sinful human spirit residing in all of us does not want to recognize the Creator and struggles to remain separate from His Word, separate from an accusing conscience pointing to an accountability. Scientific knowledge may still be gained by pursuing only material and formal causes, but without the other two causes it always remains inadequate.

Writing about the place of reason in the theology of Martin Luther, who was well-trained in Aristotelian thought, Professor Siegbert Becker said,

"Luther would have said that just this is the basic error of modern science--it professes to know more than it knows. In reality it can find only material and formal, or instrumental, causes, but in its ignorance it imagines that it has found efficient and final causes. It is this attitude which is behind the 'scientific' assertion that diseases cannot be caused by devils because they are caused by germs, or that God cannot answer prayers for rain because rain is the result of the interacting of complicated meteorological factors. Man, with his reason, can only deal with phenomena, and he ought to be conscious of the limitations which this places on all of his investigations. Reason has no way of pressing behind the phenomena to find the real efficient cause which controls and determines them." (Siegbert W. Becker, THE FOOLISHNESS OF GOD, page 66, quoted with permission of the Northwestern Publishing House)

Aristotle's genius recognized these four causes. We are to applaud and teach that. Reading his works demonstrates the limiting reality, that apart from God's Holy Word, the Bible, efficient and final causes cannot be known correctly. That limit can be partially overcome with the gift of faith our Lord gives His believers. Science, in the context of Christian education, reaches for these causes with a faith-directed reason. We can rightfully boast that our Lord has made and now continually maintains us and our world. We rightfully remain humble, understanding His final causes belong to Him. We trust Him. We rightfully remain cautious of our certainty of the material and formal causes we teach, for they always must come from the market place, where many do not know or want to know God.

4. ARISTOTLE, THE INVENTOR OF SYLLOGISM

Aristotle wrote two great works on methods of reason, particularly logic, PRIOR ANALYTICS and POSTERIOR ANALYTICS. He was the inventor of syllogistic arguments and symbolic logic. Logical methods certainly were developed long before Aristotle, but the rigid steps, the worded formulas, were not identified. In pure syllogistic form Aristotle would identify a major premise, a minor premise, and a conclusion.

If p, then q.
If q, then r.
Therefore, if p then r.

Using scientific teachings from the Lyceum, this syllogism can be demonstrated. In times of drought much earthen matter evaporates as dry exhalations and rises above the atmosphere. These dry exhalations, upon reaching the fire sphere, at times burst into flames, which are seen as comets. Therefore, when we have a drought, a comet may occur. Identifying correct symbolic structure in all arguments permitted students at the Lyceum the use of powerful tools of analysis and certainly gave them a competitive edge over other scholars in their research studies. When a correct syllogistic sequence could be isolated from a lengthier argument of science, it was counted as a demonstration. Such a demonstration was the mark of proof.

In the days of Aristotle, two methods of reason were recognized. Reason by deduction was an argument from the general to the particular. All heavy substances gravitate to the earth. Stones are heavy substances. Therefore, when I find a stone and lift it above the earth, it will gravitate back to the ground when I let go of it. Reason by induction was an

argument from the particular to the general. I realize a few stones above the ground gravitate back to the ground. It is inductive reason that leads me to the conclusion that all stones will gravitate to the ground.

In POSTERIOR ANALYTICS Aristotle made a strong stand in favor of deductive reasoning as superior to inductive reasoning. His arguments were so persuasive against inductive reasoning that students of the Lyceum did not use it. For more than a thousand years science proceeded in all of its endeavors by declared general truths to individual discoveries resulting from the generalization. Not until Robert Grosseteste, Bishop of Lincoln, developed a school of men dedicated to inductive reason at the end of the twelfth century at Oxford was the Aristotle's warning overcome.

5. THE LASTING EFFECT OF THE LYCEUM

Aristotle remained director of the Lyceum from 335 to 323 B.C. In that time, with superior methodology of thought and a dedication to the doctrine of actuality, the Lyceum became the major scientific institution of the world by both ancient and modern standards. As a true scientific institution, it promoted the value of direct observation as a necessary support for the general premises. Major funding came from "federal" sources, from Emperor Alexander. A large museum was dedicated to preserve the countless specimens of plants and animals from all over the empire.

Alexander the Great, with his political and financial protection, permitted the school, the museum, and a library to flourish. Alexander's successful conquering campaign eliminated all Persian seaports on the Aegean Sea and then the entire Mediterranean. A continuing land sweep from Asia Minor south to Jerusalem and into Egypt united Greece behind their new emperor. Stability in the homeland permitted the growth of Aristotle's scientific knowledge. Final destruction of the Persian armed forces occurred in 330 B.C. near Arbeca, but ambitious Alexander did not quit. His conquests continued all the way to the east Punjab and down the Indus River to the Indian Ocean by 324 B.C.

The cost of such continuous warfare so far away from the homeland resulted in discontent and political unrest again for Athens. Dictatorial powers given to Alexander's governors in Greece demanded strong loyalty for the long absent young emperor. Aristotle's old political liabilities for supporting Demosthenes and his criticism of King Philip sent him fleeing Athens again in 323 B.C., turning the Lyceum over to Theophrates. Aristotle returned to his home province of Chalcidice. Alexander, extended too far east, hurriedly returned to Babylon in that same year, losing many troops and also his own life because of malaria. Aristotle, in depression over the loss of the Lyceum, died the next year in 322 B.C., and Demosthenes committed suicide.

The Lyceum continued to exist for a few generations after this. Although scientifically superior to the Academy and a strong promoter of observational science, the Lyceum faded as a separate institution, giving way to the new museum and library soon to have been built in the city of Alexandria in Egypt. The conquests of Alexander the Great and the subjugation of the world to the Greek language permitted Aristotelian ideas to be known in every intellectual center. The written works of Aristotle and others of the Lyceum thus influenced western civilization until the time of Galileo in A.D. 1600. Aristotle's explanations supported by museum specimens and recorded observations became the accepted laws of science for many centuries for the Romans, for the Muslims, and for the Christians.

Just as Aristotelian thought was gaining so much acceptance, Nearchus, commander of

Alexander's navy, sailing from the Indus River to the Euphrates, experienced the great tidal oscillations of the Indian Ocean never experienced on the Mediterranean Sea. Aristotle had left the Lyceum and soon died, not providing an explanation. Tides of the ocean eroded Aristotelian science in a way from which it should not have recovered. However, the observations of Nearchus were eventually ignored, permitting the laws of the four elements, the hydrological cycle, and the earth as the center causing all earth material and water to gravitate, to remain unchallenged for a thousand years and more. Ignoring important observations is common in the historical development of science.

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SEPARATE FROM HIS WORD

ARISTOTLE'S VIEW OF NATURE: Paradigms for the Ages, Chapter 8

Demosthenes, Aristotle, and Alexander the Great all died within a year of each other. The times and tones in which they lived were set by our Heavenly Father. In His kind providence He permitted the freedom of thought for solutions of difficult problems; He permitted the essential tension and fear needed to alternatively hide, record, and transmit ideas to other people; and, finally, He permitted the Greeks to teach and influence the thought-life of their entire conquered world. Aristotle's new and different scientific explanations of the biological and physical world and his new and different laws governing terrestrial and celestial motions were preserved in his books and spread throughout the empire and used by every race and creed for nearly two thousand years. His world view was, at least in part, absorbed by every school throughout the Middle Ages. That world view dominated Medieval and Renaissance literature. It was the base of scientific studies at the University of Wittenberg and was quoted favorably as well as ridiculed by the reformer Martin Luther.

Any future revolution in science, any new way of viewing or explaining nature would have to answer Aristotelian criticism and, finally, overthrow Aristotelian laws of science. The sciences of Aristotle, biological and physical, terrestrial and celestial, are in this chapter treated as a unit in order to provide a view from the center of the earth to the sphere of divine harmony and the unmoved primary mover. Without question, views of nature which are accepted by all practitioners of science for many centuries can be spoken of as laws. They are views of nature that often stand unchallenged or undebated and which scientists use to extend knowledge and to extrapolate beyond the known.

No system of thought in science, no theory, no law, no classification system, no observationally interpreted collection of facts has stood the test of time as well as those of the world view of Aristotle. That is an amazing accomplishment for one mind. Yet few of Aristotle's views of nature are accepted today. When we feel certain about a scientific theory or law today, the reminder of the failure of Aristotelian science is humbling. As Solomon, the wisest man, said,

"I, the teacher, was King over Israel in Jerusalem. I devoted myself to study and to explore by wisdom all that is done under heaven. What a heavy burden God has laid on men! I have seen all the things that are done under the sun; all of them are meaningless, a chasing after the wind." (Ecclesiastes 1: 12-14, NIV)

The value we derive from Aristotelian science is a better understanding of the nature of science. From Aristotle's scientific works we may learn how correct he was and how wrong he was, but also how weak a new system of thought is at its inception and how uncertain our laws might be that are formulated today.

1. GAPS IN THE NATURAL WORLD

One of the teachings of Aristotle that lasted two thousand years, not to be challenged until the last two centuries of our time, was the great separation of thought between the physical and biological worlds. Democritus, with his atomic theory, had taught that all

actions of living and non-living things were a result of the interaction of atoms, of which all things were composed. Aristotle separated the living from the non-living because of the vital ingredient, life itself. He stated in his doctrine of potentiality that all living phenomena moved toward mature adult life and the reproduction of life. In the non-living world, rocks as an example, such potentiality did not exist. With this great gap in thought, Aristotle looked for different explanations for things living than for things non-living.

In Aristotle's perception of the physical world, the non-living world, all things were ungenerated, imperishable, and eternal. As such, all were excellent beyond compare. The rocks, the mountains, an endless flowing river, the wanderers, the stars in their eternal existence--all were truly divine. That made them nearly inaccessible to knowledge. Aristotle avoided studying them until later in his life, saving such noble studies as astronomy for a time when he had more experience and understanding.

In the biological world, the living world, all things showed a form of generation. All things living were subject to death and decay, displaying an impure world, a corrupt world. In spite of some of these negative properties, the biological world was accessible. Aristotle could collect many different living things and could observe their generation. His doctrine of actuality, that things observed by the senses really existed, and, in fact, had more meaning than Platonic ideas of the mind, encouraged such studies and invited contributions of both money and new living specimens from Alexander the Great as he marched all over the Empire. Plato's Academy, with a closed mind to observable things, had no use for new things brought from beyond Persia and from the Indian Ocean, but the Lyceum did.

2. THE LADDER OF NATURE:
A Biological Classification

Aristotle and his school, the Lyceum, made detailed studies of over 540 different animal species, starting with an initial collection made along the coast of Lesbos. The impact of many new living things, never known in Greece, caused a struggle over methods of classification. Aristotle's works list several methods used by others. Since opposites were frequently seen in nature, grouping of living things by pairs of opposites, winged and wingless, footed and footless, were common. Aristotle rejected this method because it broke up "obvious" and "natural" groups. Classifications by opposites were futile and impossible according to Aristotle's reasoning. He also rejected classification by organs within each kind of animal for its locomotion, its ability to move. Finally, he rejected classifications by different modes of reproduction.

His system arranged all living things in a scale of perfection, his "ladder of nature." Guided by his two doctrines of actuality and potentiality, Aristotle placed man on the top rung of the ladder because of man's possession of reason, which no animal had. Descending the ladder of nature, there was a hierarchy, according to an imagined scale of perfection in reproduction. The animals more perfectly formed at birth were higher on the ladder of nature than those animals which required additional development after birth. Next, continuing down the ladder, Aristotle grouped those animals not born, but hatched. He further distinguished among them according to potentiality. Perfectly formed, hard shelled eggs of birds led to a higher placement for birds than fish with their imperfectly formed shell-less eggs.

For a modern demonstration of Aristotle's system, the ladder of nature showed man on top. Mammals stood on the next lower rung. In descending order were whales, birds, reptiles and fish, octopus and squid, jointed shell fish, insects, mollusks, and, finally, the

lowest forms of animals, zoophytes, such as coral and sponges. Below all these animals were ranked the higher plants and then the lower plants. The ladder was then supported by inanimate matter. In a compromising fashion, unable to show a perfect ladder, jelly fish, ascidians, and some kinds of sponges hung on the sides near the rungs of mollusks and zoophytes.

It is especially important for us in these modern times to read about these ideas of Aristotle, but not with modern eyes. His ladder, from the simple to the complex, was a teacher's tool, not an interpretation based on an evolutionary ascendance. Aristotle had no thought of one species changing into the next higher species. Each kind of living creature in the actual world was seen with some change normal to nature but not changing into an entirely different creature.

Two thousand years later, in an industrialized Victorian England, when human life was forced into a mechanized way of living, where the white English race dominated the globe and believed itself superior, it was easy for Alfred Russel Wallace and Charles Darwin to build an evolutionary ladder of nature. After the same two thousand years, when some English colonies revolted and became the United States, where self-reliance and civil disobedience grew strong, where a personal judgment could evolve above the law, it was easy for such an evolutionary philosophy to dominate the new nation's literature. Scientific men of Harvard, Asa Gray and James Dana, followed the literary arts with such individual independence and developed a supporting classification system for species to climb the ladder of nature by changing themselves and separating themselves from the creation written of in God's Word.

Aristotle was quick to reject all other classification systems except his own. Such a rejection is common in science. All other classification systems in existence at the time of Charles Darwin were also rejected in favor of the one supporting Darwin's evolution. Yet an infinite number of methods could be invented by people of science, for all classifications are arbitrary. What is not arbitrary is the life forms in nature. Because of the great variety in nature, no system of classification has worked completely. All have failed. Aristotle in his own lifetime experienced difficulties with the placement of sponges and jellyfish. No system of classification has survived as long as Aristotle's ladder of nature. In time it failed and was replaced by another.

Yet biological knowledge cannot grow without classifications, no matter how strong or weak. A classification system interprets how the plants and animals are observed. Today all such observations are done with the evolutionary system. Not even creationists have been bold enough to start a new classification system. Our children must learn the system of mammals, reptiles, and fish. Accordingly, our children will be taught a whale is a mammal. With that lesson comes a true fear that the child will grow and be taught by others, naturalists at camp grounds, narrators for nature programs on TV, or professors at the university, to believe that the whale is an animal climbing the evolutionary ladder, pushing to the sea surface, preparing the way toward land life. As teachers, we will not be influential enough to change the classification system; scientists will. As teachers, we must teach God's Word, and although scientific classification systems are not part of the Bible, God's Word does say plants were created after the land was formed on the third day. Life in the sea and air was created on the fifth day, land animals on the sixth day. Adam and Eve as the first man and woman were created in a special delicate way after all other life on the sixth day. Is His classification based on habitat? We cannot say for sure. For very different reasons other than scientific reasons the Bible shows a classification system for animals in the Levitical Law. As teachers we can show scientific classification systems as human inventions with historical changes and with dependence on human thought. This dependence is far different from a dependence on God's truth. The child

surely will see the difference.

3. THE POTENTIAL IN NATURE

Aristotle's doctrine of actuality and a classification system organizing living things from the simple to the complex based on potentiality directed experimental biology toward the importance of dissection. During Aristotle's time the dissection of living creatures was forbidden. At the same time Aristotle himself called the dissection of dead creatures humbling. With the tool of dissection, the structure and function of biological organisms could be properly observed the way they really worked. Aristotle recognized two separate parallel blood systems and particularly the two chief vessels, the aorta from the heart to the arteries and the vena-cava seen coming from the heart to the veins. All other vessels were seen as offshoots from these two large vessels carrying blood to all parts of the body where the blood was consumed.

The study of blood vessels presented a paradox common in science, where the processes used to learn interfere with nature, changing it in such a way that what was pursued cannot be known. Blood vessels were largest when an organism was alive, but while the organism was alive, the tracing of the interior vessels was impossible. Only the visible exterior blood vessels could be followed. Once an organism died, its vessels contracted, and although the vessels could be followed during dissection, they were quickly lost due to their contraction. It was not until four hundred years later that Galen, a surgeon for the Roman gladiators, while attempting to put back together some of the sports heroes after disemboweling sessions, could see where some organs and vessels went, making use of these permissible, living, partial dissections.

Potentiality served as an important paradigm in Aristotle's biology. It directed experiments with plants. Aristotle showed that certain parts of plants could be continually torn or cut off and those parts would grow back. Seeds always produced whole plants. Some plant cuttings developed roots, branches, leaves, flowers, and seeds to start new plants. Thus, potentiality meant growth by development. Seeds, eggs, or live births did not begin with miniature complete organisms, but developed into them.

The most noteworthy observational experiment was that of the embryology of chickens, developed by Aristotle and copied in every school of biology ever since. The developmental process in nature actually could not be altered or controlled. Developmental changes, however, could be isolated and carefully observed. Aristotle took twenty or more fertilized chicken eggs, which were all laid the same day, and gave them to several hens for brooding. Each successive day he took one of these eggs, broke it open, and carefully observed the development of the chicken embryo. Aristotle's first sighting of an actual embryo occurred after three days of incubation. The yolk moved toward the pointed part of the egg. The heart then appeared as a speck of blood in the white of the egg beating with life from the first observable moment. Aristotle witnessed two blood vessels growing out of the heart that eventually developed a network of blood fibers enveloping the yolk. The chicken's embryonic body developed as a white thickening substance around the heart, showing a head with sensitive relatively large eyes. The lower portion of the body did not develop until last. By the tenth day a complete body of a chicken with all of its parts was evident. The blood vessels by that time appeared as two systems. One spread throughout a sack enveloping the yolk and coming to the chicken as an umbilical cord does in the higher animals on the ladder of nature. The second system of blood vessels was throughout the chicken's body and became less visible as the embryo developed. In time the yolk diminished, the chicken grew, a thin layer of fluid of the egg white in a sack surrounded the chicken as it moved

and displayed periods of rest and restlessness. During the last days much of the fluid dried and some downy feathers appeared. On the twentieth or twenty-first day the chicken pecked its way out of the egg shell. Still more time and care by the hen was needed before the final development into an adult chicken could take place. For details one should read Aristotle's own words in Book VI of HISTORIA ANIMALIUM.

The concept of development, part of Aristotle's potentiality, was never questioned. Twenty-one eggs did not confirm potentiality, but potentiality interpreted the observations. Throughout Aristotle's writings he made conclusions on the development of all forms of life and, in particular, the development of the human fetus, which paralleled the growth of the chicken. With every new life, Aristotle concluded, potentiality led to a completely new organism formed in the likeness of the parent, but the organism was always new and different. Without such a developmental paradigm as potentiality, the twenty-one egg openings would not have been important and perhaps not even done for many generations. The innovation of ideas above the observations push the senses into regions of nature not common to the senses. This is a mark of science, given a special signature by Aristotle who believed first in potentiality and actuality and then observed the same.

4. THE PHYSICAL WORLD

Aristotle divided the physical world, the universe made of non-living matter, into two different regions separated by a second great gap equal to the gap in knowledge that separated biology from physical science. This second gap separated the terrestrial world from the celestial world. The terrestrial world was governed by one set of natural laws; the celestial world followed a different set of natural laws. The boundary between them was the Eudoxian sphere, holding the moon. All things non-living below the moon were imperfect and corrupt. In this terrestrial world changes occurred continually. Time was finite, with respect to the existence of things. Non-living things, though not subject to growth and decay, nevertheless displayed a wearing out, an eroding, as a type of decay. The region of space below the moon obviously was also finite as time was. Motions of all things from below the moon to the universal center, the earth itself, occurred along straight lines or along non-perfect curves.

The celestial world displayed perfection with all motions in paths of circles following positions on rotating perfect spheres, thus remaining in concert with Plato's astronomy assignment. The celestial world was unchanging and divine. In this unchanging sense time was infinite, without end. Space, even celestial space, was finite, culminating in the sphere of Divine Harmony.

The chief element of the finite universe was aether, holding the spheres and giving a continuous substance for all things to move in. Aether also penetrated into all parts of the terrestrial world but did not participate with any transformation. Aether, however, did play an important role in establishing the consistency of many substances. Aether also helped eliminate the atomic concept of empty space or a void.

When we consider motion of any object in any place, on earth or above the earth, the existence of space filled with aether rather than a void required a physics of actuality to maintain motion. Motion could exist only if a force was present. No object could maintain motion without an observable physical force attached to it causing that motion. With the force removed, all objects in motion would rapidly stop moving and come to rest. Stones, dirt, sticks of wood grown from the earth--all would gravitate to the earth, the resting place of substances of their kind. Air, fire, and similar substances without force attached would

levitate to regions above the atmosphere but below the lunar sphere and come to rest. A feather would fall slowly to the earth because its original connection to a bird and its formation of fluffy air-like substances gave it some levitating properties. Most of the feather was made of substances from the earth. Thus, the feather would gravitate to the earth, coming to rest among substances of its own kind. This, then, was the famous demonstration of light objects falling more slowly than heavy objects. It would become a major point of controversy in the modern era of Galileo Galilei. However, it remains true that in the observable world of everyday occurrence, objects fall in proportion to their weight. In Aristotle's day as well as today, heavier rain drops fall faster than lighter ones. All objects moving horizontally, prevented from following the effects of gravitation or levitation, require a force to move, or else they will come to rest. Aristotle correctly argued against the existence of a void, since in a void an object with a force pushing it would move faster and faster without friction and achieve an infinite speed. An infinite speed would mean an object in three dimensional space could change its position instantaneously, which was absurd to Aristotle and should also be to us. Yet Aristotle's ideas of motion in Galileo's day were quickly rejected. Such is the subtlety of nature that we see so many interpretations.

5. ARISTOTELIAN CHEMISTRY

In the terrestrial world Aristotle believed all substances were made of four finite elements--earth, fire, air, and water--which could transform into one another with some limitation. Aristotle's doctrine of actuality led him to reject the relationships of Platonic or Pythagorean solids. He rejected the coexistence of opposites, as did Anaxagoras. Water could never be transformed into fire, and earth could never be transformed into air, at least not in one direct transformation.

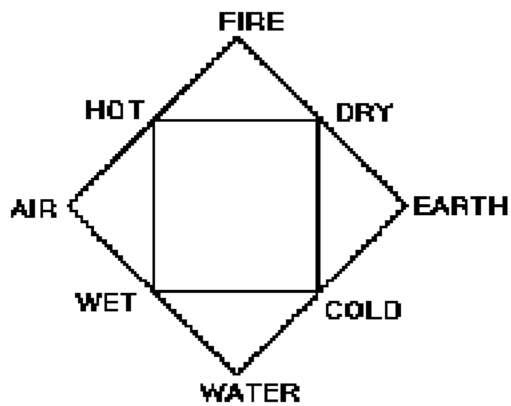

FIGURE 8.1 ARISTOTLE'S DIAMOND OF MATTER.

Aristotle's chemistry is best understood with his diamond square diagram (FIGURE 8.1). An outer square standing on a point had an element placed at each point. Fire was placed on top, water on the bottom, and air and earth on the opposite horizontal points. In this diagram the non-transforming pairs are deliberately on opposite corners. Each element had two properties, and these were placed on the sides between the elements. Fire was hot and dry, air was hot and wet, water was wet and cold, and earth was cold and dry. Water, sharing the property of wet with air, could be transformed into air by turning its cold property into hot. Aristotle called this transformation evaporation. Cold dry earth, sharing the property of dry with fire, could be transformed into fire by turning cold into hot. Water could never be transformed into fire without first being transformed into either air or earth.

Aristotelian chemistry permitted mixtures of the elements in different concentrations without transformations to give different consistencies of substances. Aether, a non-transformable substance, played such a role, changing the densities of many other substances. Mixtures and multiple transformations produced all of the metals from their fundamental element, water; their liquid property revealed their true origin. The making of alloys by mixing liquid metals, such as liquid tin and liquid copper to produce bronze, added supporting observational evidence that all metals were of a water origin. When Aristotle combined mixtures with transformations, he could explain most substances.

Basically, this science of materials worked quite well. Where some predictions about materials failed, the corruptibility of the terrestrial world provided a reason for such failures.

6. ARISTOTLE'S CELESTIAL WORLD

In the perfect spherically-shaped unchanging world, Aristotle searched for efficient causes for the witnessed motions. The closest wanderer or planet, the moon, revolved around the stationary spherical earth in an orderly pattern once every twenty-eight days, changing phase, oscillating high and low in the zodiac band in the sky. Requiring a cause from above, Aristotle concluded each higher planet caused the motion below it and received its motion from a still higher sphere. This line of reasoning took him to a position higher than the sphere of stars. Above the stars the primary mover that did not move moved everything below. Aristotle's doctrine of actuality required that if such a mover was needed in the explanation, then such a mover actually existed. Such a primary mover also had to have a motive, the final cause. Love and desire to do so were such final causes, attributes of a person. These, then, were attributes of a god ruling over his domain. Aristotle's living god was changeless and far above even the celestial world and certainly far beyond personal involvement in the terrestrial world, which was stationary, left only to witness what occurred above it.

It is interesting to see the power of reason reaching such a conclusion that a god indeed exists. Aristotle's god was dedicated to the task of moving the spheres but was far removed from the people. That false teaching played a major role in the organized church of Europe when Thomas Aquinas inculcated Aristotelian thought into all of the church's teachings. In this intellectualizing of the Christian faith, the students of Christ were robbed of their faith and given instead work-righteousness with a god above the stars, unreachable by the believer.

The primary mover that did not move resided in the stationary sphere of divine harmony. It moved the sphere of stars in one grand motion, spinning it on its axis at the star polaris one full turn in twenty-three hours and fifty-six minutes. Attached at another point on the moving sphere of stars by an axis was a primary but invisible sphere. Lower and attached to the first primary sphere by an axis was a second primary sphere. Moving downward concentrically were two more primary spheres, giving four invisible spheres below the sphere of stars, each moving at a constant rate, spinning about an axis. Each axis, in turn, was attached to the sphere above it at some point. The most distant planet, Saturn, was a light source on that fourth primary sphere, displaying retrograde loops as it wandered beneath the regularly moving sphere of stars when witnessed on the stationary earth far below. Aristotle provided for three concentric successive reacting spheres to cancel out the Saturn motion, followed by four more primary spheres of motion, which gave the witnessed motion of Jupiter. Again, three reacting spheres cancelled Jupiter's motion. Then followed five more primary spheres for Mars. Four reacting spheres cancelled Mars' motion, and five more spheres gave the motion to Venus. Four reacting spheres and five primary spheres followed for each planet, Mercury, the sun, and the moon. A total of fifty-five concentric interlocking spheres was thus used by Aristotle, building on Eudoxus' work before him. These were the spheres of constant perfect order in the unchanging celestial world.

7. METEOROLOGY OF THE TERRESTRIAL WORLD

Still concentric, but less perfect in order of purity and possibly density of substance, were the elemental spheres below the moon. These were the spheres of aether, of fire, of air,

of water, and of earth or earthy exhalations. Today we might call this sphere of earthy exhalations a layer of atmospheric dust. The motions of these spheres were most complex, resulting from the addition of all fifty-five spheres above them as well as their own. These elemental spheres were not the pure element alone, but were somewhat mixed; yet they were as pure as could be found on the corruptible earth. For example, the fire sphere was composed of mostly pure fire, remaining practically invisible, but flaring up when and where impurities collected or where other elemental transformations occurred. Also, the motion of these terrestrial spheres, as a result of the motion from above, was not perfect, causing varying speeds and frictional scrapings against each other. The atmosphere was the final sphere attached to the lowest elemental sphere and thus displayed the most complicated motions witnessed from the spherical stationary earth below.

Since air has the properties of hot and wet and fire has the properties of hot and dry, both readily levitated from the earth's surface to their proper place in their respective spheres. As the sun shone upon the earth, the cold, wet water was heated. The cold property was transformed into a hot property, which transformed water into air. At times Aristotle identified such evaporations as vaporous air to distinguish them from earthy evaporations. The sun warmed the earth, making cold, dry earth somewhat hotter, causing the element of earth to rise as dry exhalations, as a smoky substance. It levitated until it reached the sphere of earthy exhalations. These hot, dry exhalations, upon mixing with the sphere of fire, could burn. When they were moved very rapidly, being close to the zodiac region where the multiple motions of the spheres above caused the most rapid speed of the elemental spheres, they ignited or heated up and transformed into more fire, rising and at the same time giving off light.

At times such rapid increased motion occurred with the many additions of spherical turning that these dry exhalations would be squeezed either upward or downward in a pressurized manner, revealing a bright, long streak of fire, sometimes called shooting stars. At times, when this streak of fire was shooting downward into a cold region of the atmosphere, the dry exhalations, which originated from the earth, would condense to form a stone and fall to the earth. "Chasms" and "trenches" of blood red, yellow, green, and purple would occur in the sky (perhaps the aurora) when parts of the air sphere transformed into fire or dry exhalations. The fire or dry exhalations condensed as flammable earth substances and burst into weak flames when heated from the rapid spherical motion and would rise into the fire sphere. The many colors occurred by filtering the weak fire light through the dense air. The "chasms" and "trenches" got their appearance from multiple reflections off the thick air below the sphere of fire.

Comets, longer lasting and well-defined in appearance, resulted from the same cause as shooting stars, "chasms", and "trenches." Condensed materials of dry exhalations collected in the zodiac region and caught on fire by the rapid motion of the denser, slower burning earth substance gathered in this manner. These then were the slow burning comets. They were, however, rare, since most substances in the rapidly moving region of the zodiac already were burnt quickly as shooting stars before much accumulation could occur. During extremely hot and dry times, when rivers dried up and the air became less moist from the lack of vaporous air, more earth evaporated as dry exhalations. These excess quantities of dry exhalations from the earth, collected in a more dense fashion, provided the longer lasting fuel to feed the flames above the earth, but below the moon. Thus, comets were only seen during times of severe drought.

Aristotle rejected Anaxagoras' and Democritus' concept of the Milky Way. It could not be that more stars were visible only when the sun's rays were blocked from that region of space as the sun moved around the earth. To an observer on the stationary earth, the

Milky Way was visible in the same position against the sphere of stars. Yet the sun continually was changing its position. If the Milky Way consisted of stars visible relative to the sun's motion, then the Milky Way would have to appear to take different positions, but it did not do that. Aristotle contemptously announced that it was absurd to believe the Milky Way was made of stars. The stars remained on the most distant of the moving spheres. The Milky Way was a phenomenon below the lunar sphere, and this is why Aristotle classified it as a meteor. The Milky Way was again part of that continuum of fires above the atmosphere among the elemental spheres. In a great circle different from the zodiac, where motions of the spheres above caused a convergence of matter but not with the high speeds of the region of the zodiac, a continuous band of flame was caused by condensations of earthy exhalations, which burned as they rose into the sphere of fire and by air transforming into fire. This band of visible fire was the Milky Way, where most constellations were witnessed. Just as the sun was a cause for much of the lifting, heating, and convergence of the flammable material for fire phenomena in the great circle of the zodiac, so the constellations collectively caused a similar lifting of exhalations, which was higher above the earth but below the lunar sphere, where they continually but faintly burned as the visible Milky Way.

As we come down from the fire and air sphere, the elemental sphere of water, for Aristotle, was the chief source of all water on the earth. As an invisible sphere, it was not liquid water, but a vapor indistinguishable from air. Hot, wet air when cooled at the heights above the atmosphere, but below the lunar sphere, became cold, wet water of the clouds. Most of it fell as sweet rain water, spread over the land, filled the rivers, and flowed downward to the Mediterranean Sea and the oceans. The pure or sweet water was the lightest and levitated toward its place among the elemental spheres, but since the salty sea water and silty earth-laden river water was heavier, it gravitated to the deep, to the ocean. The natural place of the water still remained in the sky, so that sweeter water on the top of the ocean or in the lakes was transformed by heat from the sun into air and rose to the elemental spheres, again keeping the sea level always the same.

Aristotle believed that the ocean, the places of the deep, had no springs or currents. Therefore, there was also no mixing of ocean waters. The salt in the ocean, as well as the silty, tasty substance of river waters, came from dry exhalations of the earth, which evaporated at ground level, levitated as a smoky air to the elemental sphere, and condensed along with water to form clouds and rain. It was a fact that brackish rains always came during the fall season in Greece from Libya (Africa), giving a specific demonstration of what Aristotle believed to be a correctly established general law of dry and wet exhalations.

Some water in rivers came from springs. Aristotle taught that the springs were a result of vaporous exhalations condensing in the earth, where it became cold just as the same air condensed in the sky when it became cold. Under the pressure of the earth around it, the water was forced outward as springs and fast moving streams.

Wind was identified as dry exhalations from the earth, specifically from springs, where this type of air gushed out of the ground from all the pores of the earth. Aristotle argued from the general to the specific that wind could not be the motion of air, since air, like the ocean, did not move and had no current. This conclusion was based on the factual evidence presented by the Mediterranean Sea, which had no current and no measurable tide. Only spring water moved as a stream. Only streams of air moved as wind. The wind was generally strongest during the day, since the warmth of the sun evaporated the air from dry exhalations of the ground. At night the reverse process occurred. The air cooled, condensed as it rushed back into the earth and frequently by doing so caused earthquakes.

As a point of comparison later in our study, Aristotle's explanation of a rainbow is important. First of all, Aristotle taught that a person's sense of sight depended on rays emanating from the eye itself. More distant objects could not be seen, since these eye rays of individuals had a limited reach. The color black occurred when rays from the eyes of an individual could not extend any more and sight failed. A rainbow then was the sun seen reflected in the water of a cloud. The nearest color was the strongest and was seen as red. More distant was green, with the farthest being seen as violet. When the lines of sight going to the red and to the more distant green were very close to each other as they fan out from the eye, between them it would look yellow. Only three real colors existed in the rainbow--red, green, and violet. Sometimes a person could strain and make his sight stretch out farther and see other reflections of the sun, making a second but fainter rainbow. Aristotle claimed the order of colors was reversed because sight again saw red as light from the sun, which was closest. The light of the sun seen in the circles of the second bow changed color with distance, becoming green and violet as sight became weaker from stretching so far.

8. TRUE SCIENCE; NOT NECESSARILY TRUE NATURE

Aristotle's view of nature was truly scientific. His doctrine of actuality kept his explanations close to nature, the final test of reality. It was, in fact, this closeness to nature, this exacting fit that the laws of Aristotle could achieve that might explain their longevity.

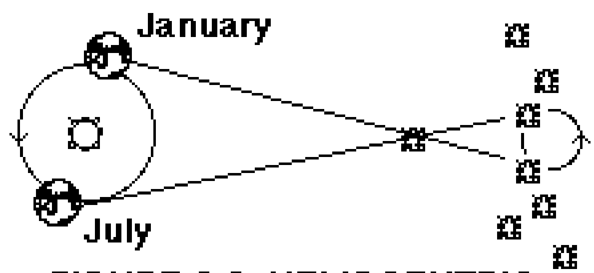

FIGURE 8.2 HELIOCENTRIC PARALLAX

Before every explanation of his own, Aristotle refuted all opposition with an exacting demonstration or detailed observation. There were many different explanations for the motions of the planets, for example. The reader will recall some Pythagoreans claimed the earth moved as a planet. Aristotle refuted such ideas with the obvious observation that when viewing things from a moving object, the observer must see the reverse motion in the near objects compared with the distant background. If the earth moved, everyone who believed such a Pythagorean idea must see the reverse oscillatory motion among the nearby stars compared to the more distant stars (FIGURE 8.2). We will see the historical detail of these arguments unfold in subsequent chapters. This much must be said now. Aristotle was absolutely correct on this demand. If we believe and teach the earth moves, we must be able to witness the reverse motion among the stars. Pythagoreans failed to show such motion. Copernicus will fail to see such motion in A.D. 1530. Galileo will use a telescope in A.D. 1600 and fail to see the phenomenon, which came to be called heliocentric parallax. By A.D. 1704 Newton will invent a telescope a hundred times more powerful using unaltered reflected light, which did not have to pass through a glass lens. Newton will fail to see the motion Aristotle demanded must be seen. Another century after Newton will go by without such observations. Think of it; a Pythagorean-Copernican system, the teaching of a moving earth, was accepted and taught as true for three hundred years without answering the observational demands of Aristotle.

This is how the laws of science are developed. They are truly laws of men who struggle to

explain what our Lord maintains for us. What ordinances our Lord made and now uses is another matter quite separate from the views of mankind. If there are laws of science which trouble the Christian teacher, remember the development of science as seen in history. Ideas of people in science do not wait for irrefutable evidence before acceptance.

Sometimes accepted laws of science are so convincing that they prevent further discovery. How much did Aristotle's scientific logic, leading to the conclusions that currents in the ocean did not exist and that neither could air move in the general atmosphere to produce wind, prevent a relearning of global navigation? Without an organized wind system and ocean currents, ocean travel was impossible. The stagnant ocean would be a barrier. Without ocean currents and winds worthy of study, naval powers of Greece, Rome, and others of Europe feared the great ocean sea. Even the surprising data brought back to Athens from the Indian Ocean for Aristotle was ignored. Nearchus, admiral of Alexander the Great's navy, ferried the army from the Indus River in India to the Euphrates River on the Indian Ocean. That ocean turned out to be very different from the Mediterranean Sea. High tides were encountered for the first time by Alexander's navy. These tides were a major anomaly for Aristotle's ordered laws of conservation of water in the hydrological cycle. Such data could have played a major role in drastically changing Aristotelian science, even eliminating the law of conservation of water or the hydrological cycle.

Pytheas, a Greek scientist and navigator from the Greek colony of Massilia in Gaul (now France), explored the coasts of Spain, France, the British Isles, and Norway or Iceland. He, too, witnessed incredible tides along the shores of the Atlantic Ocean and made note of their relationship to the motions of the moon. Rapid currents in the open sea north of the British Isles were also encountered. From his description of the sea, it is believed Pytheas crossed the Arctic circle. Pytheas described the very short night of the Arctic as "the sleeping place of the sun." As one who accepted Aristotelian chemistry, he described the edge of the permanent drift ice of the Arctic Ocean as a mixture of air, sea, and land, material transformation on a grand scale, a region which could not be crossed by ship or on foot. When such reports reached the Lyceum, Aristotle had died. His disciples rejected these tales of tides, ocean currents, icebergs, pack ice, and thick fog because they did not fit the unified science developed on the beaches of the Mediterranean Sea. The tides of Nearchus were ignored. Tales from Pytheas were recorded as lies and lay dormant until given favorable support by the famous modern Arctic explorer, Fridtjof Nansen, in his work IN NORTHERN MIST, A.D. 1911. Once more history provides evidence that scientists through all ages repeatedly choose data supporting their world view and ignore data that calls into question their preferred laws.

9. A LUTHERAN RESPONSE TO ARISTOTELIAN SCIENCE

We do not quote much from Martin Luther concerning science. We should. There are some outstanding examples that the modern teacher can use by studying Luther's writings on Genesis. When writing about the creation of the "firmament" (KJV) or the "expanse called sky" (NIV), Luther quoted from Aristotle, to explain the scientific belief of his day. Aristotelian laws of science proclaimed fire existed in the uppermost place of the terrestrial world. Water, according to science, could not exist above the firmament or the expanse.

"But Moses says in plain words that the waters were above and below the firmament. Here I, therefore, take my reason captive and subscribe to the Word even though I do not understand it." (LUTHER'S WORKS, Vol. 1, p. 26, reprinted by permission of the

Concordia Publishing House)

Luther was very tolerant of scientific views and did not throw out the science of his day. At the same time he was quite clear on his priority of trust and belief in the Word of God over the science of men.

Since these phenomena were noted by experience as elementary facts, men were induced to assign to fire the upper most place, the next to air, the third to water, and the lowest position to the earth, because it weighs the most.

"These concepts have value as first principles. Although someone may maintain that they are not universally true, nevertheless they are true in general and are useful for the proper communication and instruction of the arts. Even though fire can be drawn from flint, this is no reason to deny that the upper most region has fire in it. Therefore theology has added to the arts this rule, which is not adequately known to the philosophers: that even if by His Word God has established and created all these things, nevertheless He is not bound to those rules in such a way that He cannot alter them according to His will. We see that neither grammar nor the other arts are so bound to rules that they do not have their exceptions. In the same way fairness moderates the laws of states. How much more can this happen in the instance of God's actions! Therefore even if we know from experience that those four elements are arranged in that order and have been assigned their positions, nevertheless God can go contrary to this arrangement and can have fire even in the midst of the sea and maintain it there, just as we see it hidden in the flint." (LUTHER'S WORKS, Vol. 1, p. 27, reprinted by permission of the Concordia Publishing House)

Even the concept of spontaneous generation, taught by Aristotle, was accepted by Luther but God, not Aristotle and definitely not nature, was given the credit for such generation. Aristotle taught mice were generated from decayed materials given the power of generation by the heat of the sun, similar to the transformation of the elements by the sun. Luther in faith trusts first God's creative power and subjects all scientific thought to the knowledge given by God's Word.

"The sun warms; but it would bring nothing into being unless God said by His divine power: "Let a mouse come out of the decay." Therefore the mouse, too, is a divine creature and in my judgment, of a watery nature and, as it were, a land bird; otherwise it would have the form of a monster, and its kind would not be preserved. But for its kind it has a very beautiful form--such pretty feet and such delicate hair that it is clear that it was created by the Word of God with a definite plan in view. Therefore, too, we admire God's creation and workmanship." (LUTHER'S WORKS, Vol. 1, p. 52, reprinted by permission of the Concordia Publishing House)

We recall that Aristotle taught a nature in and of itself for the biological world. For the existence and origin of mankind, Aristotle traced backward eternally the generation of mankind, each person from a set of parents before, those parents coming from parents preceding them. In order to conclude a beginning, Aristotle claimed that a man and the sun brought mankind into existence. With such a rejection of God as the Creator, Martin Luther gets a little rougher.

"Therefore let us learn that true wisdom is in Holy Scripture and in the Word of God. This gives information not only about that matter of the entire creation, not only about its form, but also about the efficient and final cause, about the beginning and about the end of all things, about who did the creating and for what purpose He created. Without the knowledge of these two causes our wisdom does not differ much from that of the beasts, which also make use of their eyes and ears but are utterly without knowledge about their

beginning and their end."

"Therefore this is an outstanding text (Gen. 2:21). The more it seems to conflict with all experience and reason, the more carefully must it be noted and the more surely believed. Here we are taught about the beginning of man that the first man did not come into existence by a process of generation, as reason has deceived Aristotle and the rest of the philosophers into imagining. The reproduction of his descendants takes place through procreation; but the first male was formed and created from a clod of the field, and the first female from the rib of the sleeping man. Here therefore, we find the beginning which it is impossible to find through Aristotle's philosophy." (LUTHER'S WORKS, Vol. 1, p. 125, reprinted by permission of the Concordia Publishing House)

In our times the laws of science are no longer from Aristotle. They are from Copernicus, Newton, Einstein, Lamarck, Darwin, and Gould. As teachers, we find some laws of science exciting to teach; some we are unsure of; some we know are wrong. All are developed separate from His Word. His Word is still the same and true. Our teaching should still be like Luther's.

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SEPARATE FROM HIS WORD

ALEXANDRIAN SCIENCE:
A Museum and a Library, Chapter 9

The Greeks, originally a nation of islands, always were a sea power on the Mediterranean Sea, and the Greek merchants turned a profit by trading in every port where their navies went. Thus large numbers of Greeks settled in colonial coastal cities of Egypt. In a long-standing jealous hatred for the Greek merchants (as far back in the past as the reign of Egyptian King Ahmose II, King of Egypt 569-525 B.C.), the Egyptians kept the Greeks confined in the port city of Naucratis, a free trade port on Egyptian soil similar to the modern British trade colony of Hong Kong on the coast of China. With the conquest of Egypt by Alexander the Great, Greeks won the freedom to settle anywhere in Egypt.

The great conqueror founded his namesake city, Alexandria, on a land isthmus between the Mediterranean Sea and Lake Mareotis which was connected to the tributaries of the Nile in its delta. Such a placement of a seaport permitted the trade of material goods from deepest Africa along the Nile with the rest of the Mediterranean world. Alexandria quickly became a major seaport of the world, a cosmopolitan city of all races coming together for trade and a center for international scholarship with a wide base of experience for an exchange of ideas. Perhaps Alexandria was to have been the capital of the world. It was in Alexander's ambitions, after he had conquered the east, to regroup his armies and march west to conquer Italy, Africa, and Gaul (France). As we know, that was not to be.

Greek colonies were very strong in southern Italy and on the eastern half of Sicily. Already in Pythagoras' time in the sixth century B.C., Greeks in Magna Graecia, a Greek colony in Italy, were uniting against the Italian tribes. In Alexander's time the city of Syracuse on Sicily was a major Greek port from which Greek navies confined the Carthaginians, the old Phoenician race, to the western half of the Mediterranean. With the early death of Alexander the Great at the age of thirty-three in 323 B.C., a dream of a westward campaign died also. Without such a conquest, a new race was allowed to grow and unite in Italy around the city of Rome. These new Romans soon would be in a century of war for survival or elimination with Carthage and would emerge to march back across the same ground as Alexander to become the nation of iron, the Roman Empire. Following the death of Alexander, the quarreling Greeks, jealous of each other and rivals of the Macedonians, could not hold their kingdom together. Four military generals of Alexander took over and divided his empire among themselves. General Antigonus ruled over Anatolia (Turkey today), Syria, and Palestine. General Cassander ruled over Macedonia, the Hellenic League including Athens, and many of the islands. General Ptolemy I Soter ruled over Egypt and the north coast of Africa to the gulf of Sidra, the frontier of the Carthaginians. General Seleucus ruled over the remainder east from the Tigris and Euphrates Rivers to the Indus River.

Greeks were Greek. Ambitious and jealous men cannot remain at peace. Almost as soon as the dividing of the Alexandrian Empire took place, the Greek generals were at war with one another. Antigonus brought the Ionian provinces and the Island League under his control by force and lured the Hellenic League away from Cassander. The wars of the Diadochi (323-275 B.C.) were in full swing using horse, spear, and sword. Greek fought Greek, forcing many into bondage to do battle for the sake of their own security. By 300 B.C. the Seleucid Kingdom took the city of Antioch and marched over Palestine from the north. The Ptolemaic kings pressed north taking Jerusalem and the entire Mediterranean coast of Palestine. The Jews, who had returned home from bondage in Babylon and

Persia, now saw their homeland fought over by rival Greeks. Many Jews were encouraged to settle in Egypt to assist with Greek trade; thus large numbers of Jews accepted Greek as their language and Alexandria as their city.

In the west in 280 B.C. under the leadership of a Greek, General Pyrrhus, an attempt to unify Greek colonies in Italy was quite successful, and the newly expanded Roman threat was defeated. However, with the Romans willing to accept incredible losses of their armies and with a strange temporary alliance with Carthage against the western Greek navies, Greek hopes of territorial dominance over Sicily and Italy faded. By 275 B.C. Rome controlled most of Italy and Syracuse was the last Greek colony hanging on to the eastern coast of Sicily.

1. THE CITY OF ALEXANDRIA

For the uninvolved, war can be most prosperous. During these confused treacherous times the city of Alexandria prospered because it was protected by a strong navy and received much wealth from the spoils of distant wars. As a world trade center, Alexandria's harbors beckoned sailors from the lighthouse called Pharos, a tall tower built of stone, square at the base, octagonal in the center, and cylindrical on top. It reached four hundred fifty feet above its base, taller than a forty story building of today. It was built not for safety, but to show the splendor and wealth of the Ptolemaic Kingdom.

As a part of the wealth and added as part of the palace grounds in Alexandria, a temple of the muses, daughters of Zeus and patrons of the humanities, was built in great splendor. The nine muses included a patron for history, lyric poetry, comedy, tragedy, dance, erotic poetry, hymns, the glory of the heavens, and epic poetry. Under these nine muses all of Greek knowledge fit and to honor these gods, things of their providence were collected at this temple, the Museum of Alexander.

King Ptolemy I Soter brought to this museum the best Greek scholars of the Alexandrian Empire. In addition to his supporting wealth and his intellectual interests, the King brought Demetrius and Straton to the museum to direct it. Both these men had studied under Aristotle and Theophrastus at the Lyceum in Athens so it is not surprising that this museum also showed a collection of real items following Aristotle's doctrine of actuality. The museum carried on the highest level of research formerly done only by the men of the Lyceum. The tradition of the "brain power" following the money certainly was common in this Alexandrian age. As a world class scientific research institute, the museum had a room dedicated to astronomy and a large collection of astronomical instruments. Anatomical dissections of all animals as well as human cadavers were routinely performed at the museum. Large botanical and zoological gardens were part of the museum following Aristotle's tradition of collecting and classifying the flora and fauna of the entire known world. The world's most important ancient library was also a part of this museum. The Aristotelian method of learning all about a subject, beginning with the known accepted knowledge and then finding criticism of it and finally establishing new knowledge from reasoned logical deductions and observations of the actual phenomena, encouraged such a library.

At the library of Alexandria all of the Greek traditions were preserved, all of Aristotle's works, and many of the written works of the scholars at Athens. As the library's collection grew, so did its reputation, and soon any scholar who was somebody sent his books to Alexandria. Also, once the collection became famous, there was a strong desire to keep it that famous among competitors. Ptolemy III (242-222 B.C.) required all travelers to submit all their books for inspection, and titles not in the library at Alexandria were copied or

confiscated. It is not certain just how large the library became. Some records show a library of 100,000 different rolls at the death of Ptolemy I Soter and three quarters of a million rolls at its peak. At this center, knowledge was both gathered and spread.

2. EUCLID AND HIS GEOMETRY

Euclid (330-260 B.C.) was a student of the Academy in Athens who came to Alexandria to escape the political turmoil of Greece proper. He was trained in abstract thought by disciples of Plato. The cosmopolitan city, the museum, the library, and the federal grants were most suitable for him to establish a school of mathematics for the purest form of reason and the language of science. Thirteen books were preserved which today we identify as THE ELEMENTS OF GEOMETRY. With these great books came the unity of all mathematical thought. Euclid developed exacting definitions and identified five postulates that had to be accepted without proof. From these, many theorems could be proved through exciting and exacting step-by-step arguments which still dominate a tenth grader's life in our academic culture more than two thousand years later. The confidence of proof based on consistent rules gave powerful tools with which to measure and interpret nature. The dependence of science on mathematics as unified by Euclid was emphasized by Albert Einstein in the modern twentieth century when he said, "If Euclid did not kindle your youthful imagination, then you were not born to be a scientific thinker."

Euclid built his entire geometry on the circle and the straight line, two powerfully symbolic figures for the scientific Greek. Pythagoras and Plato both held that the circle was divine and perfect and part of all that was celestially perfect. The straight line was a symbol of corruption and therefore limited to the terrestrial world. These thoughts strongly followed Aristotle's logic and defined the great gap between his terrestrial and celestial teachings. The work of merging lines and circles in mathematical expression, yet keeping their pure separation, gave Euclid his high reputation and the recognition of the importance of THE ELEMENTS OF GEOMETRY in his own time throughout the known world. The thirteen books are difficult covering all of plane and solid geometry rather rigorously. Of the thirteen books preserved until today, six of them are dedicated to geometry and three are dedicated to the theory of numbers. Other interests of Euclid, including optics and an interesting treatment of irrational quantities, are dealt with in the other books.

Eight other books, the lost books on the elements of geometry, are quoted by scholarly contemporaries of Euclid. These books seem to have covered topics of mathematical relationships with respect to music, expanded upon Pythagorean ideas of musical harmonies with respect to the planets, and exposed the fallacies of geometry. Speculation on what sort of fallacies exist in geometry is intriguing. Are we today teaching errors known as such to the ancients, but lost to us now? How much of such lost knowledge must be relearned? Have we already relearned it? Or will some future generation be shocked at our foolish acceptance of certain ideas as true when in fact they were based on fallacy? Relearning is common in human history. We have seen that ocean navigation had to be relearned and the New World had to be rediscovered.

The understanding of mathematics, a thinking process using numbers, is not easy. Nevertheless, mathematics is the language of science. Too often a knowledge of science is attempted without laboring over its language, and as a result great misunderstandings occur. King Ptolemy I Soter asked if there was a short cut to the understanding of the ELEMENTS. Euclid replied that there was no "royal road" to understanding geometry. A mathematician's interpretation of nature, a Pythagorean or Platonic abstraction of nature, can provide powerful predictive values. This lure makes the struggle to understand THE ELEMENTS OF GEOMETRY worth-while.

In THE ELEMENTS OF GEOMETRY Euclid came up with some shocking concepts. He proved that there was no limit to prime numbers. Remember that prime numbers are whole numbers that cannot be divided by any other whole number than itself and one and still give a quotient that is a whole number. Some prime numbers are 1; 2; 3; 5; 7; 11; 13; 17; 19; 23; 29; . . . ; 6,553,769; . . . . It is obvious that the number two is the only even prime number. No other even number can be prime. This might not be a shock to us, but to the Greeks, having accepted the Pythagorean concept that nature responds to numbers as gods and that even numbers were infinite and odd numbers had to be finite and orderly, Euclid's infinite prime numbers shook the foundations of science. The core of understanding, that nature was orderly, suffered a set back. The number gods, particularly the orderliness of the one and his odd number gods holding that order as finite could not hold nature finite and orderly when in fact, there were an infinite number of odd primes. With order requiring a limit and with no limit possible in numbers, perhaps no order existed in this framework.

Another shock came from Euclid's work with irrational numbers. An irrational number is a number that cannot be expressed as a quotient of two whole numbers or as a fraction when both numerator and denominator are whole numbers. Another way to express this is to say an irrational number in decimal form has no ending of successive decimal places and never forms a repeating sequence of numbers or a repetend. The square root of two is such an irrational number. The Pythagoreans recognized this irrational quality for the number two and used it to show that even numbers, especially the two, were the embodiment of chaos. At Alexandria, Euclid showed that PI, the ratio of the circumference of a circle (the most perfect shape) divided by its own diameter (a straight line which divided the area of a circle exactly into two equal parts) was irrational. Pi equalled 3.14159 26535 89793 23846 26433 83279 50288 41971 69399 37510 . . . . Again Greek logic expected that the circle, a symbol of perfect order, could be subjected to numerical values known by man. Euclid found that no matter how perfectly the dimensions of a circle, identified as the circumference and diameter, were measured, drawn, or calculated, errors and inaccuracies always would remain. It was not just a case where human limitations had to be overcome with more knowledge. Euclid had proved PI could not ever be known perfectly. After Euclid's findings about PI, Plato's assignment, to find or to prove that the wanderers, the planets, moved in paths explainable by circles and spheres, could never be achieved with exactness in very fundamental ways.

The most interesting idea written by Euclid in THE ELEMENTS OF GEOMETRY was in the first several pages of the first book. Euclid gave to history five postulates that must be accepted without proof for geometry to work.

"1. It must be accepted without proof that we can draw a straight line from any point to any point."

"2. It must be accepted without proof that we can produce a finite straight line continuously in a straight line. Another way of saying this is that if we extend a straight line drawn with the first postulate, the extension will also be straight."

"3. It must be accepted without proof that a circle can be described or made using a center point and a distance."

"4. It must be accepted without proof that all right angles are equal to one another."

These first four postulates are quite straight forward and accepted. The next postulate is different.

"5. It must be accepted without proof that if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles."

Truly this fifth postulate can not be proved. Where mathematicians have tried and succeeded, they ended up with a different and more elaborate postulate that had to be accepted without proof. The genius of Euclid was that it appears he started with the five most basic postulates that he could have. In mathematical systems where this fifth postulate is not accepted, new, different, non-Euclidian geometries arise. Euclid tells us rather directly that in mathematics, where words like "proved," "true" and "certain" are used quite frequently, the power of correct answers rests on postulates which are accepted without proof. Using different postulates will lead to different mathematical systems and different answers.

Astronomy for centuries followed Euclid. In our twentieth century, after Albert Einstein's special and general theories of relativity, non-Euclidian geometry is used where the sum of the angles in a triangle have less than one hundred and eighty degrees or where the sum of the angles in a triangle have more than one hundred and eighty degrees. In these cases light travels along lines that meet farther away than predicted by Euclid, and in other cases such lines even meet on the opposite side of the base line in Euclid's fifth postulate. The meaning of this kind of reality is not important here. We must see again in Euclid's postulates an art form which human beings used to describe the natural world in which our Lord has placed us.

3. ARISTARCHUS OF SAMOS

An elaborate observatory for astronomy existed at the museum at Alexandria. The measuring instruments consisted of planar sun dials, gnomons, and large precision armillary spheres. The armillary sphere needs some explanation. It consisted of several great circle bands concentric to a point and all of the same radius. One such band might be positioned horizontally and a second vertically. Each band had precision markings on it enabling an observer to measure in three dimensional polar coordinates angles of elevation above the horizon and azimuth or degrees around the horizon starting at some arbitrary point. Thus the position of any object in the sky could be recorded relative to the earth. A third circular band could be tilted with respect to the horizon and match the center line of the zodiac or the equinox. Another such band could trace the equator of the sphere of the stars and still another could mark a polar great circle. With such tools the entire sphere of stars could be mapped and exact paths of the planets, the wanderers, could be traced against the background of stars. Such measurements were taken and kept daily and over several centuries gave Ptolemy in A.D. 150 a most remarkable record of the heavens.

The first major astronomer to use this observatory at Alexandria was Aristarchus, a self-claimed Pythagorean scholar born in Samos in 310 B.C., a student from Athens, perhaps from the Academy. He became a fellow or teacher at the museum at Alexandria shortly after Euclid and immediately began to apply THE ELEMENTS OF GEOMETRY to the sky. Aristarchus began his astronomical work ON THE SIZES AND DISTANCES OF THE SUN AND THE MOON, claiming the moon receives its light from the sun. He also accepted the concept that the moon orbited the earth. Since this was thought to be true, the geometry of such motions then showed a right triangle between the earth, moon, and sun when an observer saw an exact half moon. The distance between the sun and the earth would

then be the hypotenuse with the right angle at the moon. Using the precision measuring devices at Alexandria, Aristarchus measured the angle from the earth between the moon and the sun as 87 degrees. Using the concept of similar triangles which have correspondingly proportional sides, Aristarchus could calculate that the sun was nineteen times farther away from the earth than the moon.

The face of the sun, when viewed from the earth, is almost exactly the same apparent size as the moon, and this is dramatically seen during solar eclipses. Using calculations similar to those used to calculate distance between the sun and the earth, Aristarchus calculated that the diameter of the sun was nineteen times larger than the moon. Lunar eclipse measurements gave the sun's diameter as 6.75 times the diameter of the earth. With relative diameters, relative volumes could be calculated. The sun was calculated to be 311 times larger than the earth and about 7000 times larger than the moon. None of Aristarchus' calculations were absolute. All were relative to the unknown size of the earth. The exact size of the earth would be calculated in the next generation by Eratosthenes, a scientist of the Alexandrian museum.

Aristarchus' mathematical methods were excellent. As a Pythagorean, believing first in the completeness of the number ten and including the earth as a planet, Aristarchus found it logical to place the sun as the largest body in the stationary position of the center of the cosmos. He taught that the earth spun on its axis once a day, the moon orbited the earth once in twenty-eight days, and the earth orbited the sun once a year. Just as other heliocentric proposals failed the Aristotelian scrutiny, Aristarchus' system for planetary motion with the earth moving failed. He could not show the existence of the earth's motion in the opposite motions among the nearer stars (heliocentric parallax). He tried to explain that the stars were so distant from the earth that the earth's orbit, even when actually very large, comparatively appeared as nearly a point. Thus opposite motion that ought to be seen among the stars from the earth should not be seen. He postulated that the nearly infinite distant stars were fixed and motionless when compared to the earth. Such extreme distances, however, were not acceptable to the scientists of Aristarchus' day. Again we see how for each age the authority of the practicing scientists is most influential.

4. ARCHIMEDES OF SYRACUSE

Archimedes, an engineer with mathematical abilities equal to Euclid, brought scientific fame to his distant Greek city of Syracuse. The city of Syracuse was a Greek colony founded by Corinth on Sicily in the days of Pythagoras when Magna Graecia was flourishing. When Archimedes was born in 287 B.C., Rome was expanding throughout Italy pushing the Greeks out. With the whole of Italy under Roman control, ambitious Roman leaders learned the skills needed for building a navy and with it came the long bitter struggle against the Carthaginians, formerly the Phoenicians, who were also the old enemies of the Greeks. Syracuse and Carthage fought each other continuously for dominance of Sicily, but with the entrance of a third party, the fresh new Romans, all of Sicily fell to Rome by the end of the first Punic war in 241 B.C. Greek Syracuse, with a strong defense and payment of tribute to Rome, managed to keep its independence.

Pressures of war often stimulate a scientist as they surely did for Archimedes. As an engineer, Archimedes designed and supervised the building of catapults, battering rams, and countless other siege machines later perfected by the Romans. It is even reported, in mythical proportions, that Archimedes built land-based reflecting concave mirrors and convex lenses with long focal lengths that focused the sun's rays and burned up invading Roman ships before they reached shore.

For his work in astronomy Archimedes built a large orrery, a series of concentric transparent glass spheres which modeled an Aristotelian planetary system. With water driven hydraulically moving parts, the orrery could predict the motion of the planets and eclipses. As a world-renowned scientist, he was invited several times to the museum at Alexandria and may have built such an orrery for the museum. The literature of the day shows exchanges of ideas between Archimedes, Aristarchus, and Eratosthenes. Using information from Aristarchus, particularly his mathematical methods, and the size of the earth from Eratosthenes, Archimedes published the distances of all the planets from the earth. Some scholars claim Archimedes used musical harmonies and mathematical sequences of the Pythagoreans to arrive at these numbers. It remains uncertain. His distances, translated into statute miles, are given below.

Distance from the earth to:

moon,	63,000 miles,
Venus,	5,800,000 miles,
Mercury,	8,200,000 miles,
sun,	14,000,000 miles,
Mars,	19,000,000 miles,
Jupiter,	23,000,000 miles,
Saturn,	26,000,000 miles,
zodiac,	28,000,000 miles.

It was Archimedes who became the legendary first streaker, running naked in the streets, forgetting he just left his bath and hollering "eureka" to tell his King Hieron that he had solved the problem of specific gravity and could distinguish between gold plated silver and pure gold by merely submerging the objects in water. Archimedes noticed his body displaced the exact same amount of water each time he sat in a tub. These principles of specific gravity, that objects which sank displaced their volumes in water, that objects which floated displaced an amount of water equal to their weight, and that the proportion of their body submerged was equal to their density as a fractional proportion of the density of water, were discovered in the abstract with immediate practical application.

This was the genius of Archimedes. Directly related to his sprinting nude to the King was his application of buoyancy, that a known weight of gold would displace an exact amount of water when submersed, no matter what its shape was. Silver mixed with gold to fool the King, even with its heavy weight, could be detected since the density of silver was less than gold. The silver would displace a larger volume of water than an equal weight of pure gold. The cheating metallurgist lost his head.

A most complex theory of forces relating to ideal levers led Archimedes to build the large number of practical war machines for which the Roman engineers who copied his ideas became famous. Archimedes identified three classes of ideal levers (FIGURE 9.1). Most junior high school children have learned the first class lever as a teeter-totter in which an effort force pushes down on one end of a lever and a resistance force also pushes down on the other end with a fulcrum providing an upward force somewhere in between. The closer the fulcrum could be placed to the resistance, the greater the mechanical advantage--the numerical value of the resistance divided by the effort. It was this simple lever that permitted Archimedes' boast, "Give me a place to stand on and I can move the earth." In fact, he did lift a large ship full of passengers and all of the ship's stores out of the water using only one arm and a system of levers.

A simple second class lever was constructed of a fulcrum providing an upward force at one end of the lever, an upward effort force at the other end with a downward resistance force between them. A wheel barrow is an example of that second class lever.

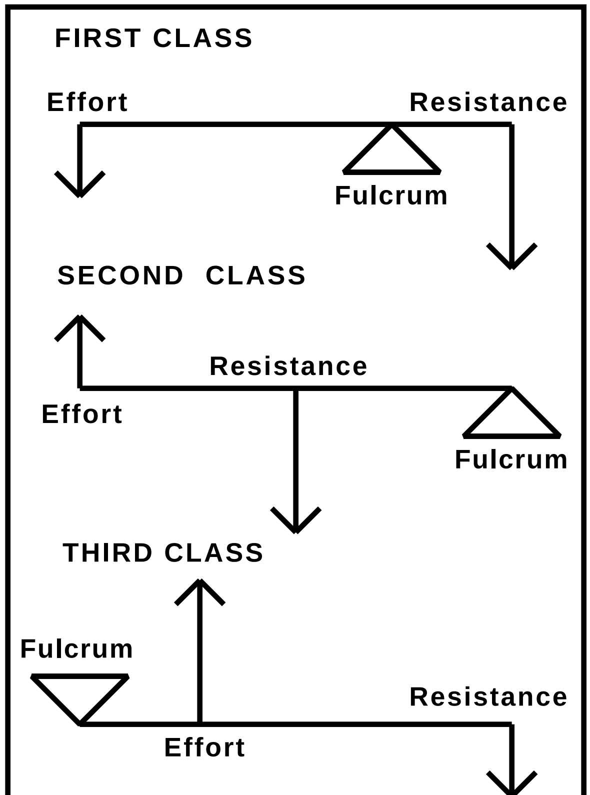

FIGURE 9.1 LEVERS

A simple third class lever had a downward directed fulcrum at one end of the lever. The effort force pulled upward along the lever with the resistance downward at the other end of the lever. The human arm is such a lever in which mechanical advantage is given up for the sake of speed.

Archimedes did not win his fame with just simple levers. His mathematical genius showed very complex lever arms governing all shapes, curves, and sizes. In essence he merged mathematically two types of equilibrium--translational equilibrium where the weight upwards and downwards had to be equal for balance and rotational equilibrium where clockwise torques (a complex vector product of the lever arms and forces that alone would cause spinning motions) equaled counterclockwise torques.

For complex levers in which shape and size play a part in the mathematics, Archimedes imagined the system as a summation of many infinitesimal little systems all acting simultaneously. His mathematics thus predated the invention of calculus by 1900 years. As a forerunner to the calculus, Archimedes' mathematics showed that regular polygons merge into circles as the number of sides increase without limit.

Imaginatively he took a line segment (remember such a path was representative of corrupt motions of terrestrial science), rotated it about its mid point at an angle in three dimensional space, and swept out two cones. If either the upward or downward pointing cone was cut by a horizontal plane, an intersection gave a perfect circle (a path of perfection reserved only for celestial science in Greek thought). By slightly tilting the intersecting plane, the circle transformed into varying ellipses. If the plane was tilted far enough to be parallel to a side of one cone and not intersect it while still intersecting the first cone, the ellipse would suddenly break open into a parabola. Further tilting so as to cut both cones resulted in a path of intersection that showed a hyperbola (FIGURE 9.2). Archimedes demonstrated that there was nothing special about circles. Conic sections could generate circles from a variety of impure curves, even from a point and shockingly from straight lines.

These conic sections caused an incomprehensible challenge to the essence of order which the perfect sphere and circle provided the followers of Platonic astronomy who were seeking answers to the motions in the heavens. What did Greek science do with such challenges to the core of its methods? From Archimedes it learned that circles and spheres were not marks of special order and from Euclid it learned through irrational numbers that measurements of such circles or spheres could never be made with perfection. Greek science did what most sciences historically do when their fundamental paradigms are challenged. The practitioners ignore such challenges!

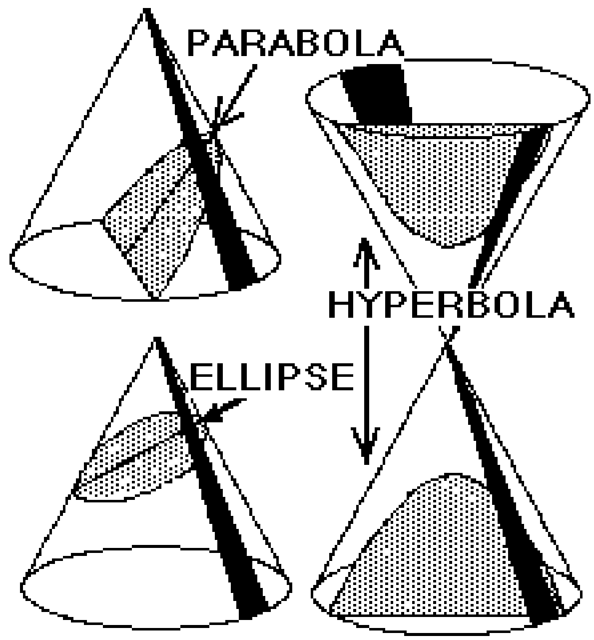

FIGURE 9.2 CONIC SECTIONS

Solutions for planetary motions were sought along Platonic circles and spheres until Johannes Kepler in A.D. 1609 explained the motions of the planets in terms of Archimedes' conic sections, primarily ellipses. Physics started to deal with uncertainty in measurements as part of the natural order with Heisenberg's Principle of Uncertainty first formulated in A.D. 1927.

When ideas arise in science which the Christian teacher can judge as error because of a clear doctrine from Scripture, what can such a teacher do to change science? The Christian teacher is not called to change science. It remains the task in every age that the Christian teacher should teach His Word and remain steadfast in His Word. Practitioners of science commonly ignore challenges to the fundamental beliefs of science. It may take two thousand years before the scientists in the market place realize an error.

The second Punic war between Carthage and Rome broke out in 212 B.C. The city of Syracuse and its surrounding territory, a Greek colony, had long been enemies of the Carthaginians. As Rome gained power in the west, she became a rival of the Greeks as well. With Rome pushing hard on Sicily, the peace was obtained by Syracuse through a reluctant tribute to Rome. At one point in time Carthage, under the leadership of Hannibal, inflicted major damage to the armies and new navies of Rome. With the death of King Hieron and his son, the leadership of Syracuse was reduced to a vacuum. When it became apparent to the new leadership of Syracuse that Carthage would defeat the Romans, Syracuse abandoned allegiance to Rome and tried to make peace with Carthage. Few men in authority ever comprehended the losses Rome was willing to suffer without admitting defeat. The superior Roman general Marcellus was sent to Sicily in 214 B.C. prepared to vengefully settle the score with the turncoats of Syracuse.

"So when the Romans attacked by sea and land at once, the Syracusans were at first terrified and silent, dreading that nothing could resist such an armament. But Archimedes opened fire from his machines, throwing upon the land forces all manners of darts and great stones, with an incredible noise and violence, which no man could withstand; but

those upon whom they fell were struck down in heaps, and their ranks thrown into confusion, while some of the ships were suddenly seized by iron hooks, and by counter-balancing weight were drawn up and then plunged to the bottom. Others they caught by irons like hands or claws suspended from cranes, and first pulled them up by their bows till they stood upright upon their sterns, and then cast down into the water, or by means of windlasses and tackles worked inside the city, dashed them against the cliffs and rocks at the base of the walls, with terrible destruction to their crews. Often was seen the fearful sight of a ship lifted out of the sea into the air, swaying and balancing about, until the men were all thrown out or overwhelmed with stones from slings, when the empty vessel would either be dashed against the fortification or dropped into the sea by the claws being let go." (Plutarch, PARALLEL LIVES, "Marcellus," tr. Aubrey Stewart and George Long, in Nels M. Bailkey, READINGS FROM ANCIENT HISTORY, p. 278, reproduced by permission)

Valiantly Archimedes, the Greek mathematician, scientist, and engineer, gave his knowledge and expertise for the defense of his city. The Romans several times were repulsed. With great losses, General Marcellus carried out a long, bloody two-year siege, but in 212 B.C. during the Greek festival of Artemis, the Roman army easily overwhelmed drunken Greeks of the western suburbs of Syracuse. Carthaginian armies assisting the defenders of Syracuse were at the same time overwhelmed by a viral epidemic from the surrounding marshes, and a Spanish mercenary commander was bribed to open a key gate permitting the Roman bloodthirsty army its final revenge. Our God alone controls the power and time of the nations.

A Roman infantryman suddenly came upon Archimedes, with orders to take this genius alive that he might serve Rome, but Archimedes was busy working through a difficult problem in mathematics carefully writing it all out on the ground. It has been told that when this Roman soldier marched across this "ancient chalk board" disturbing the calculations of Archimedes, the mathematician yelled at the soldier in a manner in which conquering soldiers were not accustomed. With his steel sword the Roman soldier immediately removed Archimedes' head. Saddened by the scholar's death at an age of seventy-five, Marcellus personally honored the local hero and provided for his family. The strongest and westernmost Greek colony had fallen. Though weakened in the Second Punic War, nothing remained to slow the eastward expansion of the new power from Rome.

5. ERATOSTHENES OF CYRENE

In the east, at the museum and library of Alexandria, Eratosthenes, director of the library, mourned the death of Archimedes. In the east they also became very much aware of the new growing power from Rome. Hannibal, the Carthaginian, was given political asylum in the Greek Seleucid Kingdom under Antiochus III (223- 187 B.C.) bringing Roman intrigue eastward. Antiochus III took Palestinian territory away from the Ptolemaic Kingdom, but the still strong navy of the Greek Ptolemaic dynasty kept Alexandria a stable giant trading seaport with its intellectual exchanges and scholarly work at the museum and library well protected for another century.

Eratosthenes was born in 273 B.C. in Cyrene, the westernmost coastal city of Egypt. He was educated at the Lyceum in Athens and was invited to be a research fellow at the museum by King Ptolemy III at the young age of twenty-nine, which allowed him fifty years of service to the research institution. He was one of the last great scientific generalists and at times suffered some ridicule for being such a generalist in an age in which all of the scholars brought to Alexandria were beginning to divide their work by becoming

specialists.

Eratosthenes continued the mathematical work of Euclid on prime numbers and invented a mechanical device to aid finding larger prime numbers. As a geographer he constructed crude maps showing and identifying different countries by common shapes. His most remembered accomplishment was his accurate calculation of the circumference of the earth. Eratosthenes observed a gnomon or tall pole on a day when the sun was directly overhead at the summer solstice in the city of Syene (Aswan) on the Upper Nile. On this day the gnomon cast no shadow while at the same time in Alexandria a gnomon of the same size cast a short shadow of measurable length. Eratosthenes measured the acute angle made at the top of the Alexandrian gnomon by a ray of sunshine and the gnomon itself. That angle measured to be 7 degrees 12 minutes of arc or one fiftieth of a great circle. He then reasoned that a solar ray of light coming from the sun to Syene was for all practical purposes parallel to the ray of light coming from the sun to Alexandria. The line segment of the gnomon at Syene to the center of the earth was an extension of the solar ray at Syene. The line produced by the gnomon at Alexandria to the center of the earth was then a transversal cutting across two parallel lines (FIGURE 9.3).

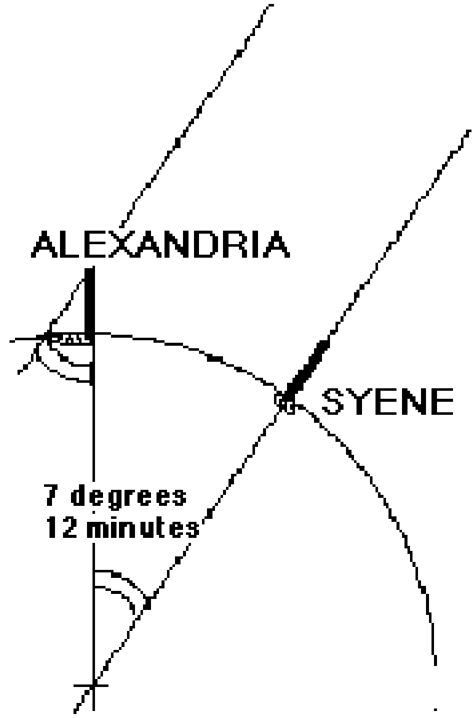

FIGURE 9.3
ERATOSTHENES'
GNOMONS.

Using a proved theorem of Euclid, that when two parallel lines were cut by a transversal, their alternating interior angles were equal, Eratosthenes concluded the angle in the center of the earth made by the lines from Syene and Alexandria to the center of the earth had to be the same 7 degrees 12 minutes of arc. The distance on the earth's spherical surface between Syene and Alexandria was known as 500 miles and now also known as one fiftieth of the great circle. This proportion yielded the circumference of the earth as 25,000 miles. For Eratosthenes it followed immediately that the distance between the earth and the moon was 78,000 miles and the distance from the earth to the sun was 80,000,000 miles.

With the decline of the power of the Ptolemaic Kings, the museum and library at Alexandria did not likewise fade away, but they did cease to be influential or innovative. They remained a center of learning well into the era of the Roman Empire.

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SEPARATE FROM HIS WORD

SCIENCE UNDER ROMAN RULE: Some First Christian Views of Science, Chapter 10

The Greeks fought endless wars among themselves. During the unrest that was encouraged by meddling Rome, Antiochus III, leader of the Seleucid Kingdom, took Palestine away from the Ptolemaic Kingdom. In 167 B.C. Antiochus IV erected a statue of Zeus in the Jewish Holy Temple in Jerusalem which started a chain of events--the Maccabean revolt, the formation of the strong political parties of the Pharisees and Sadducees, a short period of Jewish independence (142 - 63 B.C.), great hatred toward the Greeks, and a flirting with the Romans that soon would backfire for independent Palestine.

The final destruction of Carthage by the Roman legions in 146 B.C. gave Rome the entire western Mediterranean area uncontested and the lure of the east, where the Greeks remained divided, drew Rome to its empire potential. The Roman peace, brought with the Roman iron sword and shield, swept over Greece, and Pompey conquered Syria and Palestine by 64 B.C.

The Greeks did the thinking for the world; the Romans made the world obey. The Greeks believed and taught the existence of an eternal material world. The Romans only cared for the use of those materials. This new kingdom of iron provided little new for science, but with the Roman sword came aqueducts which brought fresh water into many public buildings and roads to move armies and increase wealth and prosperity through world-wide commerce. The practical Roman engineers put centuries of Greek science to the test with practical use. No invention of Archimedes or angle and arc of Euclid was ignored. Roman engineers became the masters at the use of levers and the understanding of the distribution of forces through a three dimensional structure. Roman circular arches and spherical domes testify to such brilliant application.

1. THE ROMAN ATOMIC WORLD

Among the aristocrats of Rome the teaching of the Greek philosopher Epicurus, though rejected at first, over a few centuries became a way of life. Pleasure was the ultimate end of all morality. The pursuit of genuine pleasure included a prudent life of honor and justice. Of all these things the Romans were masters. Their very pragmatic approach to knowledge accepted political and natural changes in a purely materialistic way and in a very fatalistic manner without the need of a guiding cause other than the causes from within the materials themselves. The supportive science at the base of this way of life was the atomic theory of Democritus. For the Romans, all of these ideas were artistically written in the poetry of Titus Lucretius in a series of books under the title THE NATURE OF THE UNIVERSE. This long poetic work reaffirmed for the Romans that nothing could ever be created out of nothing. Nothing could ever be annihilated. This is the essence of the Law of Conservation of Matter. All things, in particular the entire world known to the Romans, were due to atomic interaction. These interactions were a result of the motions of the atoms that make up all matter and were not a result of any outside creative intelligence. With this interpretation of nature we can understand why the only authority was Roman authority and why some rulers could make themselves god. The fatalistic view comes from atomic motions and changes that go on eternally and have no guidance, direction, or design.

Lucretius used Aristotle's ladder of nature showing the continuum of the simple to the complex from inanimate matter to plants to simple animals to higher animals and finally to man. He went one step farther claiming the creation of life actually was spontaneously formed by atomic interaction with the inanimate earth producing first plants and then animals. Lucretius wrote in THE NATURE OF THE UNIVERSE talking about atomic interaction that many animals came from the earth formed by rains and the heat of the sun. There are even hints at a "survival of the fittest" which was not formally proposed until A.D. 1859 by Charles Darwin.

One of the great achievements of Lucretius with his poem was the argument against continuous matter and the four or five elements. Those scientists arguing in favor of continuous matter believed that all objects could move, but at the same time did not permit the existence of empty space. Things in motion needed an emptiness to move into in order to have any motion at all. By pure observation of the senses Lucretius pointed out that all things had a limit of smallness beyond which they suddenly could no longer be seen. If continuous matter existed, such a sudden departure from perception would not occur, but objects would gradually fade away. Continuous matter required no limit to the size of things which crumbled. In verse Lucretius argued that there could be no sudden start of life by birth and no sudden end of life by death if matter were continuous. Exposing another error in Platonic or Aristotelian chemistry, Lucretius showed that if elements could transform from one into another, there had to be still simpler elements. In reality, he argued, there was no limit to forms of matter or species of living things. Evaporation was not a transformation of water into air, but the water in the ocean decayed as the atoms spread apart and penetrated through the air in the empty spaces until the water atoms again collected within the walls of the clouds and fell as rain. The voids between the atoms permitted other atoms to increase their penetrating motion to an almost infinite speed, reaching places almost instantaneously, moving faster even than sunlight. Thus, such a rapid transport of water to the clouds escaped visible detection. The arguments Aristotle had used to defeat the concept of a void now in Lucretius' verse supported the same phenomenon. This reverse argumentation is very common in all sciences, in all ages.

Lucretius' atoms were somewhat different than those of Democritus. The shape of the Lucretian atom was most important. All properties of substance such as color, taste, and smell were due to a composite of atomic shapes. The number of atomic shapes possible was large but finite. There could not be an infinite number of shapes or else large visible atoms would be possible. Arguing in the same vein, Lucretius claimed the number of living species had to be limited because giant sized animals were not known and did not exist. Along similar limitations the number of compounds possible had to be large but again finite. The atoms themselves were unalterable and had no sensual properties. Only by a combination of atoms could sensual properties develop. With this understanding, compounds in transition were unobservable when broken down into separate atoms.

Another Roman idea of science expounded in the poetry of Lucretius was an explanation of the clouds as a clashing war. As the clouds would grow and fight for position in the sky, they would smash into one another, break, and even explode from too much wind within them producing audible thunder. The lightning flashes and bolts were the hot sparks from the colliding cracking clouds similar to the sparks that came out of flint when struck by iron. Tornadoes occurred when too much water had entered a cloud and produced a downward expansion in the form of a funnel which reached to the ground and when breaking, would release torrents of water and violent wind.

Earthquakes occurred when water, rocks, or turbulent wind under the ground moved in a violent way. The sea remained level because of an undertow into and beneath the land masses which fed the springs. Volcanoes were brought about when fire and smoke from outside the earth, from the limitless universe, invaded a locality and caused an "infestation" where they entered the ground. This fiery rash would then erupt as an infested boil on a person's skin. Always such infestations came from beyond the earth. Plagues and pestilence occurred by similar invasions from outer space.

Once again we see science, this time of the Romans, used to describe nature separate from the pagan gods. Lucretius had a correct dislike for the evils committed in the name of religion and a proper goal to eliminate myth and superstition, but his atoms also eliminated the Creator of all. Spontaneous, accidental, random, purposeless atomic motions governed all things. Common to such a science was the spontaneous generation of life, again at random without purpose or design. This is the second time in the history of science when atomic theory and self-evolving life march side by side in a human understanding of the natural world interpreted by a sinful natural man as separate from His Word, separate from the Creator. How does such a philosophy of science affect an individual? What is it worth to a person? Not much is known of Lucretius except for a short line in Jerome's CHRONIA EUSEBII under the year marked as our 94 B.C. It was said that Lucretius became insane after taking a love potion. After writing several books he killed himself. Just a short half century after Lucretius' death, the eternal Son of God, Creator of all, was born in a Roman principality ruled by King Herod the Great.

2. ROMAN GOVERNMENTAL SCIENCE

The size of the world as calculated by Eratosthenes was known to Julius Caesar (102 - 44 B.C.) and having seen the British Isles to the far west, he was somewhat dismayed at the smallness of the world known to the Romans compared to the entire sphere of the earth. He prepared extensive plans to conduct the first world-wide survey in which all trade routes, major highways, roads, trails, population counts of the races, their habits and politics, the location and sizes of rivers and lakes, the extent of the ocean, and the climatic differences throughout the world would be recorded and mapped. A four story building of a full city block was planned to house the federal workers that would gather and maintain such an immense data base. The practical value of such a global project, the only part of knowledge the Romans considered, could readily be seen for the future control of the empire. Such a survey would aid in the effectiveness of Roman trade and thereby enhance the Roman economy. Such a survey was important for national defense and security. The republican form of government required exacting representation in the Roman Senate and such information was needed, at least from Rome's own provinces. Finally, such a survey might discover the rest of the world. The magnitude and cost of this global study, similar to a modern International Geophysical Year, cannot be underestimated. The one planned by Julius Caesar was the first of its kind. In these modern times such studies are rarely conducted. Our own national census is taken once every ten years, and these include only population counts and economic factors whereas the Julian census included many more parameters of knowledge.

World events delayed such a global study. Julius Caesar, at war with Ptolemaic Egypt led by Queen Cleopatra, laid siege to Alexandria and burned the Egyptian navy. In the burning and during the siege, a portion of the great library at Alexandria and an unknown quantity of books were burned. Julius Caesar fell in love with Cleopatra, the last of the Ptolemaic rulers of Egypt, and fathered a child by her. Julius Caesar was assassinated by Brutus, Cassius, and other senators shortly after he returned from his exploits in Egypt. Mark Antony also pursued Cleopatra in a friendly way and wooed her with great gifts, one

of which was 200,000 books forcibly taken from a competing Greek library in Pergamum. In the Roman rebellion that followed the death of Julius Caesar, Mark Antony lost to Octavius. Cleopatra committed suicide. Rome, somewhat weakened in the rebellion, set Herod the Great as king over Syria and Palestine and made it an independent, but puppet government required to pay a large tribute for the favor. Octavius became the new Emperor of Rome and was named Augustus Caesar.

The rest of this part of the history of science, the carrying out of the first world-wide geographical research survey, each of us has memorized.

"In those days Caesar Augustus issued a decree that a census should be taken of the entire Roman world. (This was the first census that took place while Quirinius was governor of Syria.) And everyone went to his own town to register. So Joseph also went up from the town of Nazareth in Galilee to Judea, to Bethlehem the town of David, because he belonged to the house and line of David. He went there to register with Mary, who was pledged to be married to him and was expecting a child. While they were there, the time came for the baby to be born, and she gave birth to her first born, a son. She wrapped him in cloths and placed him in a manger, because there was no room for them in the inn." (Luke 2:1-7, NIV)

Astronomy, not of a practical use, did not flourish among the Romans. Theories for the motion of the planets were in disarray. The models of Eudoxus and Aristotle were preserved in the library at Alexandria. Archimedes' working glass hydraulic model was lost. A large collection of astronomical star maps and tables listing the positions of the planets as they moved across the view of the stars had been gathered and maintained at the museum and library at Alexandria. These maps and tables showed many errors in the standing laws of astronomy. Meeting the challenge, all the newer men of astronomy solved their problems according to Plato's assignment. Solutions of the motions of the planets across the heavens had to show perfection and therefore had to be in terms of circles and spheres. Two theories emerged using just circles for the planets and only one sphere for the stars. These theories today are identified as an eccentric theory and an epicycle theory.

The eccentric theory showed all the wanderers moving uniformly in circular orbits around a spherical stationary earth. The eccentricity of the theory was that it did not place the center of the planetary orbit at the earth (FIGURE 10.1). This non-earth center could then also move in paths of circles. When viewed from the earth which was off center, the planets appeared to move at different speeds in different seasons. This gave some needed revisions which data collected at the Alexandrian museum demanded.

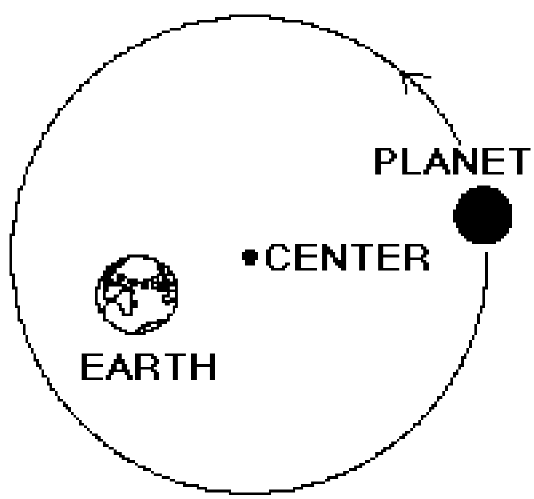

FIGURE 10.1 ECCENTRIC MOTION OF A PLANET.

In an extremely rare occurrence for science, a competitive theory, the epicycle theory, emerged explaining things equally as well. The earth remained a stationary sphere at the center of the universe. Each planet circled an invisible point called an epicenter. Each

epicenter (FIGURE 10.2) for each planet then orbited the earth. When discrepancies arose between observations and theory over a long period of time, more epicycles were added.

Both systems explained retrograde motions of the planets quite well. But there exists one and only one natural world and scientists know that. That is why it is so rare to have in the community of scientists a tolerance for two theories of planetary motion. In a time when all books of science were collected in central libraries and Roman peace allowed the ease of travel and communication, such tolerance would be short-lived. The scientists knew there could be one and only one explanation. The debate over planetary theory captivated most astronomers at the several scientific centers in the known world, though none of note were Roman. In addition to the museum and library at Alexandria, major centers of learning existed at Rome, Athens, Pergamum, Rhodes, and Seleucia. Many astronomers were gazing at and measuring the positions of the stars, in particular the wandering stars.

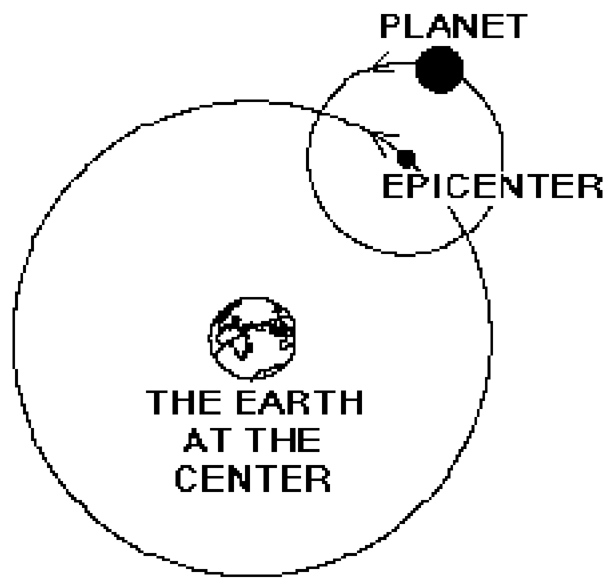

FIGURE 10.2 EPICYCLIC MOTION OF A PLANET.

During these very times the Magi in the East saw a star. These learned scientists, with eyes of faith in the Lord and His Word, stopped their research and were led to the Christ quite independent of scientific proofs or laws. Just how the Magi in the East knew that a star would announce the birth of the Christ Child remains a mystery. The prophecy, "A star will come out of Jacob," (Num. 24:17 NIV) was given by an oracle, Balaam, who was paid by Balek, the King of Moab, to curse the Children of Israel. God is in control at all times with His almighty power, even over Satan. Balaam opens his mouth to curse and the most hopeful promise to all races is given instead. But where did the Magi hear of such a promise? Daniel, governor of the Magi and special advisor to five kings, among them Nebuchadnezzar, Darius, and Cyrus, is the most likely link. What did the Magi from the East follow? Was it a shooting star, a comet, or a conjugation of planets? Many believe it was the conjugation of planets since there were two spectacular unions of planets in the sky in 7 B.C. and 2 B.C. It is unlikely that it was a conjugation because the Magi were astronomers and definitely knew the difference between a star and a planet and would know exactly what was happening as the several planets moved close together. "After they had heard the king, they went on their way, and the star they had seen in the east went ahead of them until it stopped over the place where the child was." (Matt. 2:9, NIV) It is unlikely that it was a planet, comet, or shooting star because they do not move as the star of Bethlehem moved. The ancient Magi knew that and believed they saw the true Christ, the Savior of all mankind.

What does the star of Bethlehem teach us about science? Today's scientists and

teachers of science should do just what the Magi did. They worshiped the Savior, presented Him with gifts, and "returned to their country by another route." (Matt. 2:12, NIV) The Magi returned to their work, most likely on eccentric and epicycle planetary motion, with the comfort of the knowledge of the fulfilled Promise. We must leave the great miracles of God to God as He presents them to us in His clear Word and not try to muddy their holy purpose with human ideas of science.

3. THE ROMAN SCIENCE OF GEOGRAPHY

The greatest gains for Roman science were in geography. The leading thinkers, nevertheless, were Greek. Strabo (63 B.C. - A.D. 21), a Greek by race and Stoic in philosophy, was employed by the Roman government to make maps and write a geography for Rome. He lived and worked in an old Greek colony on the Black Sea and was granted extensive travels from Egypt to Italy under a Roman signature. His chief map of the world was very similar to one by Hecateus showing Europe, Africa, and India as one land mass surrounding the Mediterranean Sea and a single ocean surrounding all of the land (FIGURE 10.3). Strabo's geography was an encyclopedia of knowledge identifying and describing all the volcanic regions and earthquake movements throughout the known world, the "rolled stones" of southern France, and climatic differences. He identified Britain as sunless, described the monsoons of India, and pointed out the southern limit of the snow line and glaciers on the northern side of the European Alps. Strabo's geography included regional tree and plant differences as well as the differences in habitation and dress of the races.

FIGURE 10.3 AN OUTLINE OF STRABO'S MAP OF THE WORLD

An advance in the science of geography made by Strabo showed the existence and importance of scientific interrelationships between the physical and social sciences. For example, Rome became a power because of the geographic safety given by the Italian Peninsula and because of its excellent natural harbors. Rome could be a world power because its varied terrain and varied temperature gave it good quantities of food products. The central position of the Italian Peninsula permitted Rome to control all the peoples of the world. This idea of interrelationships by Strabo advanced the study of geography to a new level of understanding and appear to be true and are worthy of study. The Christian also knows our Lord provides the wind and the rain, the climate. He alone made the shape of the land and the sea. They all obey Him.

4. ROMAN SCIENCE OF SENECA

Seneca (3 B.C. - A.D. 65) was a Spaniard by birth who studied and practiced law in Rome and became very successful and wealthy. Like Strabo, he too was identified as a Stoic. Many aristocrats of Rome were Stoics. It was a philosophy the Romans borrowed from the Greeks in which wise men were to be free from passion with little visible emotion whether

it be joy or grief. A Stoic willingly submitted to the national laws. Seneca wrote a major scientific work entitled NATURAL QUESTIONS. As a scientific work it displays much of the practical requirements of the Romans and also displays a lack of the in-depth thinking of the Greeks.

Seneca's scientific thought was different from that of Aristotle. He rejected Aristotle's philosophy of actuality with its four causes. He saw matter not as a material cause but simply in existence without question. Seneca saw, therefore, one and only one cause. As an example, Seneca referred to a statue that was made of bronze. Bronze was material. The cause of the statue was only the craftsman. As a Stoic Roman, who saw iron rule with stern but fair laws and justice carried out swiftly, he saw only the individual as the cause of anything formed.

Seneca is of interest to us since St. Jerome, one of the earliest Christian writers, identified him as a Christian. Whether or not he was a true believer is left to our Lord's judgment. The written record shows Seneca as a very complex individual. He claimed to have sought a simple life, but he collected usury interest rates and public bribes in his law practice. He became a government official under Tiberius. Caligula was jealous of Seneca's oratory ability and ordered him executed, but was led to believe that the lawyer would soon die of poor health anyway. The third wife of Claudius had Seneca banished to Corsica because of an adultery charge involving him with Julia. On this charge it is impossible to know if indeed Seneca was guilty since most of the aristocrats in Rome were involved with Julia. Seneca ended up as a special tutor to Nero and was raised to consular rank, eventually becoming prime minister under Nero. His most famous works were his three books ON CLEMENCY presented to Nero in the peak of the Christian persecution where Seneca tried to show Nero that saving lives was worthy of the highest reward.

Seneca made no special appeal on behalf of anyone and certainly not for a Christian. In his writings he had high praise for Nero himself. His emperor drew him into a conspiracy in the murder of Agrippina. In A.D. 65 evidence was presented involving Seneca in a conspiracy against Nero. True or false, Seneca was sentenced to be immediately beheaded unless he took his own life. He was denied the right to a will so he lanced both his own and his wife's arteries with the same stroke of his sword and died. This style of death may not necessarily be judged a suicide in the same despairing sense as that of Judas since Seneca was forced into it. In Seneca's last words he freely accused Nero of many murders including his own. I would think with his last words, even if he were a legitimate closet Christian, he would have found a way to speak of Christ. However, in times of brutal persecution it is hard to be bold. None of the disciples were bold Maundy Thursday. St. Jerome judged Seneca to be a Christian on the basis of correspondence which appears to be genuine between Seneca and St. Paul. It was Seneca's brother, Gallio, the proconsul of Achaia, who saved St. Paul from a Jewish lynch mob. (Acts 18:12-17)

For natural things, where Aristotle at first tried to let nature be her own efficient and final cause, Seneca simply believed all things consisted of matter and God. God created matter pouring it out all around Himself and then led and guided all matter. Seneca recognized the existence of limits to the human senses. He also recognized that there were limits to human understanding and reason. This is the special insight that a Roman writer, a creator of Roman law, could see in nature, that nature created by God was also governed by God according to laws He alone wrote.

The rest of science by Seneca deals with thunder, lightning, snow, rain, hail, earthquakes, comets, and other things of astronomy and physics. All of his scientific ideas were laced with duties and morals. The moralizing in science cannot be identified

with Christian teachings since it is not by our moral works, but by what Jesus Christ has done for us that we are saved. The moralizing of one as influential as Seneca did no good for the advancement of science.

5. PLINY THE ELDER

Pliny the Elder (A.D. 23 - 79) was born in Gaul (France) and was educated in Rome. He served in the military in Germany, Spain, and Gaul. He also traveled to Africa. Politically he served Emperor Vespasian and General Titus. The last office which he held was as Prefect of the Roman fleet at Misenum. Thus, all his professional life he was in the service of his country. His major work in science included thirty-seven books under the title NATURAL HISTORY which covered astronomy and physical and historical geography. He accepted the idea that the earth was a sphere and was one of the first writers to attempt an explanation of why people on the "antipole" did not fall off. He made reference to water drops, naturally spherical, hanging upside down underneath rooftops and fences after a rain. The spherical shape had this power to hold things together and to it. Pliny's special new contribution was an extensive description of plant life in Germany. He also wrote about crop rotation.

His exhaustive descriptions of hundreds of animals, though accurate, were of little lasting value since they only were a group of observations, not connected by a unifying theory of development or classification system. Quite frequently the history of science shows men like Pliny the Elder dedicating their lives to observational reporting of things in nature. Observations, no matter how carefully made, are useless to the scientist until theories invented in the minds of human beings can give meaning, define what is important, or explain what links certain phenomena together.

While stationed at Misenum with the Roman fleet, Pliny witnessed the eruption of Mt. Vesuvius. This was very exciting for a scientist and immediately Pliny began surveying the eruption from a ship. During a quiet time, Pliny visited friends at Stabiae (Castellamare) on the southern shore of the Bay of Naples. As a knowledgeable scientist he assured his friends everything was going to be alright, and that he had come to study the routine changes occurring in the eruption.

"Now it was day elsewhere, but there night darker and denser than any night, alleviated a little by numerous torches and lights of various sorts. It was decided to go out upon the shore and see at close quarters whether the sea now offered any prospect of safety; it still continued wild and adverse. There Pliny lay down upon a cast-off linen cloth, and once and again he asked for cold water, which he drank. Then flames and a smell of sulfur announcing the approach of flames, caused the others to take to flight and roused him. Supported by two slaves he got upon his feet, but immediately collapsed, his breathing, I gather, being obstructed by the thickening vapor which closed up his throat--naturally weak and narrow and frequently inflamed. When day returned--the third after the last day that he had seen--his body was found intact and uninjured, covered as he had been dressed. The appearance of the body suggested one sleeping rather than dead." (Pliny the Younger, "Letter to Tacitus")

Pliny the Elder's works were Roman and therefore practical, but showing no unity to nature, he did not advance science and did not give it direction. After the fall of Rome came the collapse of academic institutions and the corresponding loss of value for knowledge. Nevertheless, Pliny's NATURAL HISTORY and some writings of Galen, a Roman medical doctor, survived and enjoyed a longevity otherwise awarded by practitioners of science only to major works of unity or to works of revolutionary

importance.

6. GALEN AND ROMAN MEDICAL KNOWLEDGE

Galen was born in Pergamum in A.D. 129 to a Roman architect and thus was given a very practical scientific training. He studied medicine at the medical centers of Smyrna, Corinth, and Alexandria. He became the chief surgeon for the College of Gladiators in Pergamum. His medical knowledge and skill brought him much fame as the gladiators of Pergamum, whom Galen patched together, were given the high honor to fight and die in the great Colosseum of Rome. Galen was invited to demonstrate his surgical skills to other doctors in Rome from A.D. 161-165 and then returned to Pergamum to escape both jealous political enemies and a devastating pestilence brought to Rome by a returning army. Other successive calamities led to superstitious fears that the Roman gods were displeased with the growth of Christianity and another major persecution took place.

Emperor Marcus Aurelius summoned Galen to serve the Roman legion in Germany. In A.D. 168 Galen became the personal physician to Commodus, the emperor heir apparent in Rome. In the wealth of his position Galen served out his years in Rome and in leisure wrote more than five hundred books. The medical books of Galen that survived various major fires and sackings of Rome during its long gradual decline became the first medical textbooks of the new Christian era in the universities of Europe a thousand years later.

Taking advantage of the wounds of the gladiators, Galen performed several experiments on living men that were impossible to do with dissections of cadavers. It had been believed that the veins carried blood and the arteries carried air. By tying an exposed artery of a living person in two places, Galen showed that blood existed within that section at all times. By a similar technique, Galen also discovered that arteries carried a pulse wave along with the blood. He replaced part of an exposed artery of a living person with a tube and witnessed the pulsed wave. By tying off the artery, the pulse stopped. By untying it, the pulsed wave could be witnessed again.

Galen developed some of the most extensive descriptions of human anatomy both exterior and interior. He mapped the nervous system from the brain to the spinal column to many parts of the body and understood the sympathetic nervous system as having a regulatory function over many of the seemingly controllable functions of the body such as the heart, stomach, intestines, and other internal organs. He taught that life was a result of the interrelationships of three types of breath or air substance. A psychic breath flowed from the brain through the nervous system to all parts of the body. A vital breath was distributed by the blood in the heart and arteries. A natural breath from the liver was carried by the blood of the veins to its appointed places. The venous and arterial systems were truly separate systems, but both involved the heart and both sent blood with the appropriate breath outward to be consumed by the body (FIGURE 10.4).

Galen taught that blood was made in the liver with natural breath and moved in veins to the heart and to the rest of the body. The blood going to the heart from the liver entered the right ventricle of the heart. Most of the blood then entered the right atrium and departed the heart through the vena cava to all parts of the body. Galen also believed some blood from the right ventricle of the heart entered the pulmonary arteries to the lungs in a back and forth motion where it was purified and returned to the venous system again through the right ventricle, right atrium, and the vena cava. A small amount of blood somehow crossed the wall from the right ventricle to the left ventricle. Air breathed into the trachea was also brought into the left ventricle by the pulmonary veins and mixed with the blood

with natural breath. The natural breath turned into vital breath in the left ventricle. The blood then carried this vital breath to all parts of the body by blood through the aorta and on through the arteries. Vital breath carried to the brain by arteries was then transformed into psychic breath. The psychic breath could then be transmitted to all parts of the body through the nervous system.

Galen developed a unified paradigm of elements and body fluids. The digestive process consumed the four elements--earth, fire, air, and water--with food stuff. He believed that the process of combining the elements with the transforming properties of cold, dry, hot, and wet along with the three breaths produced four fluids--blood, yellow bile, black bile, and phlegm. These were vital for all body functions. If a person's blood chemically dominated the body and was enriched with a purest breath, such a person was considered sanguine, warm, passionate, having a cheerful temperament with a healthy ruddy complexion. A person chemically dominated by his phlegm was sluggish, dull, and apathetic. Galen, using his psychological traits based on dominating body fluids, taught that a person with dominating intestinal fluids, yellow bile, was an easily irritable person, one easily induced to anger. Persons whose black bile predominated were gloomy people and in extreme cases mad. Good health and psyche were dependent on well balanced body chemistry. Galen thus favored a good diet and clean living to keep the body in good stable equilibrium. It was much more difficult to prescribe medication and diet once that equilibrium was lost. Galen had a large bag of tricks or recipes of drugs, herbs, and spices. His cure-all was a concoction containing opium.

As a doctor for soldiers, gladiators, and emperors, Galen's science was most practical. He saw and recorded only what to him was obvious. He added no mythical analogies as found in much of Pliny's work. He gave no moral purpose, but neither did he reject a place for religion. He sought Aristotelian efficient and final causes in the overwhelmingly complex organs of the human being. Such a person had to be designed by a creator god with all of the complex parts of the body working together with purpose and according to a preconceived plan. Galen rejected the simplistic single mechanical cause for life. Galen believed such a creator had to be an all powerful and wise god. Such a creator had to be loving and merciful toward his creature, toward man.

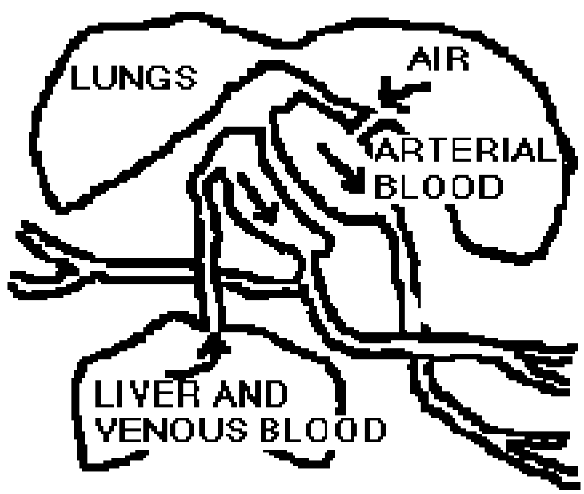

FIGURE 10.4 THE FLOW OF TWO BLOOD TYPES ACCORDING TO GALEN.

When Christianity became socially acceptable in a free open manner, Christian scholars could then turn their intellectual attention toward natural phenomena. It was this strictly practical, nearly unbiased Roman approach to science that the Christians would attempt. Galen's view could be turned by the Christian to see the true Creator of nature.

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SEPARATE FROM HIS WORD

LAWS OF ASTRONOMY BY PTOLEMY and the Rejection of Science by Early Christians, Chapter 11

The iron nation, the Roman Empire, had become soft and used its wealth to hire mercenaries for its army. The Romans preferred the comforts and luxuries of urban life, supported by non-loyal enslaved peoples. Rome never did care much for basic research, pure science, for the sake of knowledge alone but only for that which was practical and immediately useful. The research at Alexandria, particularly astronomy, was of little value to the Romans. Gliding on its past as a powerful, growing empire, Rome let the library and museum at Alexandria fall into disuse. But a Greek scientist, Claudius Ptolemaeus (Ptolemy), in the finest tradition of his people, used recorded data of planetary motions dating back to the founding of the astronomical observatory at the museum to develop the most accurate geometric model of the universe known to mankind in his day and for many centuries thereafter.

Not much is known about Ptolemy. His years of life are thought to be from A.D. 100 to A.D. 178. Outside of his books, the only things recorded about him are the dates he made astronomical observations at the Alexandrian museum from A.D. 127 to A.D. 151.

1. PTOLEMY AND THE REFRACTION OF LIGHT

Much about reflection and refraction of light was known and preserved in books in the Alexandrian library from visiting scholars like Archimedes. Ptolemy used that knowledge about bending of refracted rays of light and applied it to what was thought to be certain observational positions of the stars. A side view of a ray of light from a star to a human observer standing on a stationary spherical earth would reveal a bent path at the top of the atmosphere. If one viewed a star eastward of the vertical (FIGURE 11.1), light from the stars would strike the atmosphere at an angle and then bend in a steeper downward angle to the observer. The observer, thinking the light of the star that is seen comes in a straight line, would mentally trace the steep ray of light outward into the cosmos missing the point of bending or point of refraction and believe the stars were closer to the zenith than they actually were. A corollary to Ptolemy's idea is that the sunlight at sunset refracts through the air and can be seen even

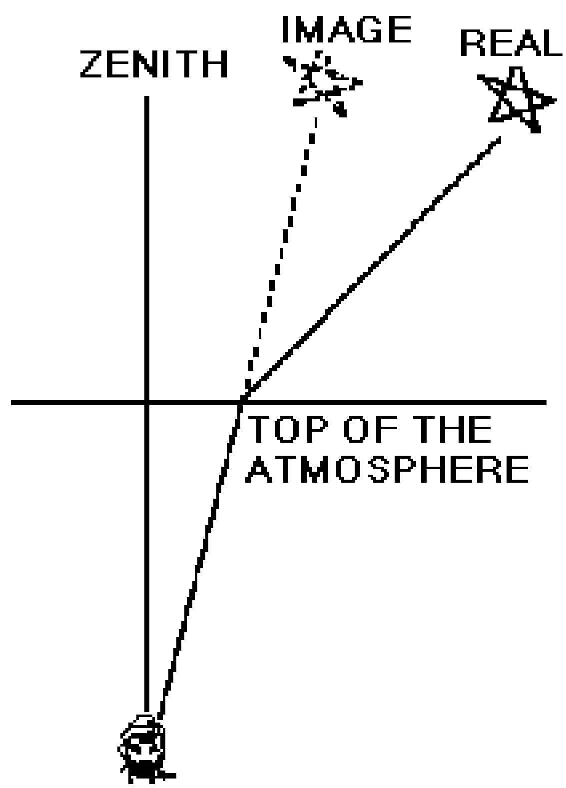

FIGURE 11.1 REFRACTION CAUSES ALL VIEWERS OF THE STARS TO SEE THEM CLOSER TO THE ZENITH THAN THEY REALLY ARE.

after the sun has geometrically set below the horizon. Likewise the sun can be seen before it geometrically has risen above the horizon.

This optical discovery by Ptolemy had the same shocking impact on Greek certainty of science as Euclid's discovery of irrational numbers or the similar shock found by Archimedes that a circle was only one particular case of many shapes that could emerge from conic sections. Ptolemy showed that because of refraction, the stars, and planets too, were not really where the observer saw them.

2. PTOLEMY'S ASTRONOMY

Ptolemy's greatest achievement, in fact the culmination of Greek astronomy, was his work of thirteen books entitled THE SYNTAXIS or THE MATHEMATICAL COMPOSITION. As science, it was a unifying mathematical treatise of the universe, bringing together centuries of observations and developing mathematical, mostly geometric, models of the movements of all stars and planets. THE SYNTAXIS did not permit any phenomenon to be explained without a complete mathematical description. Geometric circles and symmetries explained and demanded in return exacting observations and exacting fit to the mathematical analysis. The predictive accuracy of Ptolemy's mathematical composition of the heavens gave better results than could be expected with the limits of his day imposed by the naked eye. Predictive positions of the planets were within five seconds of arc to a true position or about one part error in a thousand if a degree was divided into a thousand parts. With such accuracy, Ptolemy's work became known as "the greatest work" by the Arabs who used his writings long after the fall of Rome. The Arabs knew THE SYNTAXIS as the ALMAGEST which has become the most common name of Ptolemy's work today. All motions across the sky were predictable after Ptolemy. His explanation was acceptable for fifteen hundred years. These then truly were laws of science.

First, let us examine some of Ptolemy's data. The synodic period of the planets, the span of time between successive reoccurrences of the same relative positions of a planet with the earth and the sun-planet, were known quite precisely. In Ptolemy's day, this span of time was the time between retrograde loops. The number of retrograde loops (cycles) divided by the solar time span equaled the synodic period.

PLANET	CYCLES	SOLAR YEARS	SYNODIC PERIOD
Saturn	57	59	378 days = 1.04 yr
Jupiter	65	71	398 days = 1.09 yr
Mars	37	79	780 days = 2.14 yr
Venus	5	8	584 days = 1.60 yr
Sun	1	1	365 days = 1.00 yr
Mercury	145	46	115 days = 0.32 yr
moon	421	34	29.5 days = 0.08 yr

The sidereal period of each planet, the span of time between successive reoccurrences of the position of a planet with the sun-planet and the stars, could be calculated. Such values were useful for astrological purposes. However, the sidereal period is not a readily observable value. In one day the sun falls behind the sphere of stars by 1/365.25 of a great circle path while a planet falls behind the sphere of stars by 1/P of a great circle path, where P is the sidereal period of the planet. For Ptolemy's inner planets, Venus, Mercury, and the moon, P, the sidereal period was less than 365.25 days. Thus,

$1/P - 1/365.25 = 1/S,$

where S is the synodic period. For Ptolemy's outer planets, Mars, Jupiter, and Saturn, P is larger than 365.25 days. It follows for these planets that

$1/365.25 - 1/P = 1/S.$

The sun was the middle planet. Without a retrograde loop it was a mathematically trivial case. The computational sidereal periods of the planets were:

moon	27.3 days		
Mercury	87.9 days		
Venus	224.7 days		
sun	365.25 days	=	1.00 yr
Mars	687.0 days	=	1.88 yrs
Jupiter	4,332 days	=	11.86 yrs
Saturn	10,740 days	=	29.4 yrs

To Ptolemy the earth was a sphere, stationary in the aether of the cosmos, and in the exact center of the sphere of stars. For the rest of the explanation Ptolemy employed circles, following the original assignment of Plato that the solution to the motions of the wanderers was in terms of circles and spheres. The sphere of stars turned on its polar axis once a day around the earth but exactly the 1/365.25 of a day faster than the sun moved around the earth. Because the sun moved around the earth, it was counted as a planet. All the other planets displayed retrograde loops in the sky against the backgroend of the sphere of stars. Ptolemy solved this by a double Ferris wheel arrangement of circles. The genius of Ptolemy ended the great unsolved debate in astronomy as to whether the planets moved in epicycles or in eccentric circles. The solution Ptolemy gave included both, thus ending the debate in a simple way that only a genius could.

A first circle, commonly called the deferent, not centered on the earth, surrounded the earth. Orbiting the earth counterclockwise along the path shown by the deferent was an invisible point called the epicenter. A second circle, the epicycle, centered on the moving epicenter and revealed the second counterclockwise path of the moving planet other than the sun.

Observable motions of the planets revealed variable brightness and variable speeds in the cycles of the planets. To explain such changes and keep constant angular motions around perfect circles, Ptolemy invented another invisible point called the equant. This equant lay on a line defined by the center of the deferent and the center of the earth. The equant itself was on the opposite side of the deferent's center than the earth's center. The historian of science, Charles Singer, gives a synthesis of all of the planets instead of the many individual geometric pictures for each planet given by Ptolemy. A diagram after Singer's view of Ptolemy's planetary motion, shown in this chapter, provides a "first" understanding of Ptolemy. Using Singer's synthesis of Ptolemy's teachings (FIGURE 11.2), if a line is drawn between the equant and the epicenter, the speed of the epicenter is such that this equant line sweeps out equal angles (label it angle A) in equal periods of time. The result is that when the epicenter is closest to the earth, the arc distance traveled by the epicenter in a given period of time is larger than the arc distance traveled by the epicenter closest to the equant in the same period of time. The planet then responds in its changing speeds sweeping through the cosmos in retrograde loops every orbit of an epicycle.

A second important angle, B, was made by the meeting of a line segment from the planet

to the epicenter and a line segment from the epicenter extending the equant line to the most distant side of the epicycle from the equant. The speed of the planet around the epicycle was such that the angle B changes at a constant rate. That constant rate was relative to the changing rate swept out by the equant line giving a most complex variability which could adequately describe the real motions of the subtly moving planets.

For Ptolemy's outer planets, Mars, Jupiter, and Saturn, angle A swept out a complete circle in one planetary sidereal period, thus taking Jupiter twelve years to traverse across the complete sphere of stars. Angle B swept out a complete circle once a year. For Jupiter that meant it displayed twelve retrograde loops while it made its complete pass under the sphere of stars.

For the inner planets, angle B swept out a complete circle during a planet's sidereal period. This would show Mercury making a retrograde loop every 88 days. Angle A swept out a complete circle in a year. Mercury would then loop the loop every 88 days as it took a full year to traverse a great circle of the sphere of stars.

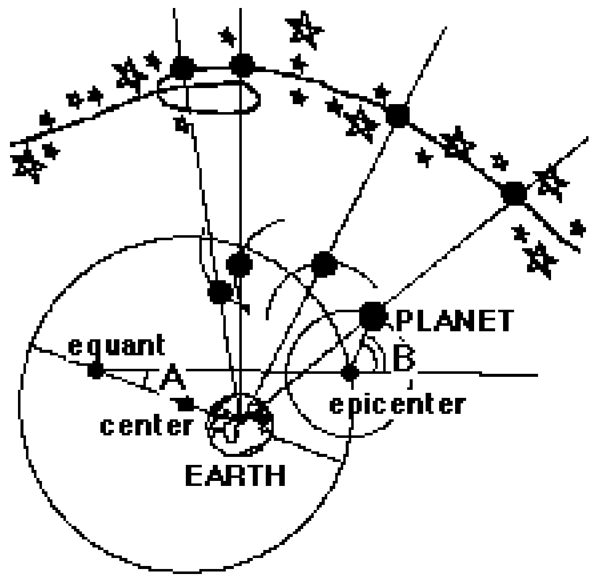

FIGURE 11.2 A COMPOSITE DIAGRAM FOR PTOLEMY'S MOTION OF PLANETS.

With his system Ptolemy was able to overcome all the written criticisms of other systems Aristotle had laid down. Other systems failed while Ptolemy could explain the variable brightness of each planet, especially Mars and Venus. His system did, however, frustrate him because he could not derive an interrelationship between each planet. He had to develop a different set of circles and equants with different speeds and at times even add extra circles for each of the different planets. Nevertheless, Ptolemy's ALMAGEST was the accepted paradigm for nearly 1400 years. It became longer lasting than any other explanation even in our own age. During the centuries it survived, it truly became the laws for planetary motion. Yet today no astronomer believes them.

Changing the laws is common in science. A scientist does not gain renown by endlessly verifying the accepted. When change came in A.D. 1530, first Aristotle, not Ptolemy, would have to be undone. Ptolemy's astronomy was superior, but it also was more complicated. A century after Copernicus, Kepler would try to achieve the exactness of Ptolemy. Not until Isaac Newton wrongly explained gravity in 1686 would Ptolemy's astronomy be overthrown. Even then Ptolemaic law fit the sky better. Heliocentric parallax would not be seen. Observations of nature have always been the arbitrator in science, and Ptolemaic laws indeed were confirmed beyond a reasonable doubt by observations.

3. PTOLEMY'S GEOGRAPHICAL WORK

The most important work of Ptolemy in his lifetime, especially for Rome, was his

GEOGRAPHICAL OUTLINE. On the recommendation of Marinus, Ptolemy's teacher, he set out to update the map of the world bringing together the work of Strabo, the data from the great census conducted by Caesar Augustus, and the newer information brought from the frontiers of the expanding Roman Empire. With his experience from astronomy, Ptolemy applied mathematics in the Alexandrian tradition to geography. He stressed distances between known important places and always cross checked such distances knowing caravaneers and sailors exaggerated their travel descriptions. To assist with exactness of position, Ptolemy invented latitude and longitude beginning with zero degrees Longitude at the Fortunate Isles (Canary Islands) and suggested Asia ended at least by 180 degrees Longitude. His map was the first attempt at projecting a spherical globe on a flat map (FIGURE 11.3). The northern hemisphere was drawn on a flat surface as a polar projection from the North Pole to a spread out circle of the equator. The known southern hemisphere was shown also on a flat surface as a cliff projecting vertically down from the equator.

It was accepted that the earth was a sphere, and it was also recognized that the sun played a role in the transformation of the elements to give the weather. The sun's position, high or low in the zodiac, or its inclination with the earth was an important measurement, different for different places on the earth. In Greek, this inclination was called the clima. Thus, five zones on earth could be measured with Ptolemy's latitudes and thereby define the climata. Ptolemy wrote of the most northerly zone, the arctic clima, as marked by severe cold and mostly uninhabited. The peoples on the fringes of the Arctic were of extreme pale "frozen" complexion with blond or white hair. An island, Thule, possibly Iceland or Greenland, existed north of the British Isles in the arctic clima zone. Ptolemy's map with these written geographical outlines showed the Asian land mass extending to the North Pole marked TERA INCOGNITA. In the middle latitudes or middle clima existed all the races of the known peoples of the earth. This middle clima had a temperate climate centered on the Mediterranean Sea. The low latitudes or equatorial clima was hot. The extension of the Sahara Desert as an uninhabitable region, burning people to very dark skin, was strongly believed by Ptolemy. The spherical earth required Ptolemy to imagine an earth with perfect symmetry with respect to climate so an antipode temperate zone existed, probably inhabited. You will recall the Greeks back to Pythagoras were very open to the possibility of races of people even among the stars. Imagining the existence of races of antipodes was acceptable. The fifth zone again symmetrically was a polar region of extreme cold, the antarctic clima.

Ptolemy's world map hinted at an earth with much more land than water. The Indian Ocean was shown as a closed ocean like the Mediterranean Sea. The east African coast below 15 degrees South Latitude curved eastward forming an Antarctic land mass attached to both Africa and far east Asia. In the Atlantic Ocean the west coast of Africa also swept westward merging with Antarctic lands, eliminating any possible thought that you could sail around Africa even though sailors in the past knew how to do it. The new beliefs in geography caused the loss of some knowledge. Knowledge in this sense is tenuous. A people might be knowledgeable of some things, but then new laws or at

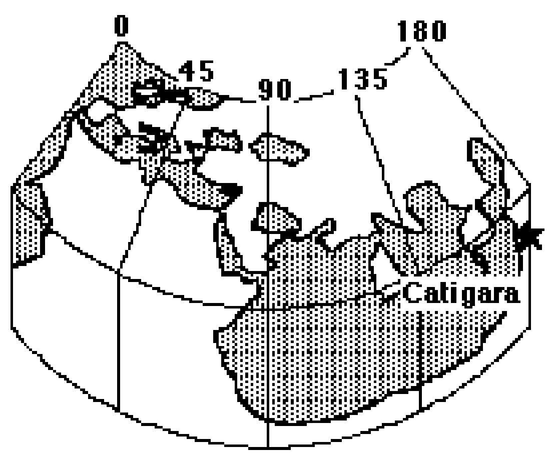

FIGURE 11.3
A RECONSTRUCTION OF PTOLEMY'S MAP OF THE WORLD

least new ways of examining things cause the loss of knowledge.

Ptolemy's measurement of the earth's circumference was considerably smaller than Eratosthenes' measurement. Ptolemy's distance was 18,000 miles and was trusted more than Eratosthenes' 25,000 miles because of the reputation Ptolemy made with his ALMAGEST. A smaller size earth could have proved fatal for Christopher Columbus; instead it turned out that he made an incredible discovery based on error.

Ptolemy's map correctly showed the Caspian Sea as a landlocked salt sea and the source of the Nile River from high altitude lakes south of the equator in Africa. The flooding of the Nile, a puzzle to science for many ages, was confirmed in the GEOGRAPHICAL OUTLINES as resulting from rapidly melting snow accumulated on the Mountains of the Moon in the tropical zone of Africa.

The early Christian scholars liked the Ptolemaic map since it seemed to fit allegorically with the holy number seven, derived from the six days of creation and one day of rest as recorded in the creation account of Moses. As there were six days, so there were six parts of land. One part of water completed the seven holy parts of the created earth. Some early Christian map makers moved Jerusalem to the center of the known world, and although some modern scholars mock these early Christians for that, when looking at an outline of Ptolemy's map, the best that was available, and adjusting things slightly for errors with India, Jerusalem really is not far from the center. Early Christians could not accept antipode people and some simply extended the tropical heat southward identifying Antarctica as an antipole with hell fire.

4. EARLY CHRISTIANS AND SCIENCE

In Rome, as a prisoner of the Empire under house arrest, St. Paul "For two whole years stayed there in his own rented house and welcomed all who came to see him. Boldly and without hindrance he preached the Kingdom of God and taught about the Lord Jesus Christ." (Acts 28:30-31) He was executed by order of Emperor Nero in one of the first major persecutions of Christians. In spite of the several persecutions, Christianity grew. But as Christianity grew, Roman power weakened. Two centuries of Roman peace gave way to invading hordes on many fronts. The Parthians challenged the eastern boundaries of the empire and later were replaced by more threatening Persians. The German hordes poured into northern Italy threatening Rome itself. The patriotism of the Christians was questioned. The Christians denied the Roman official gods who were thought to be upset at this rejection. The decline of the Roman Empire therefore was blamed on the Christians and fueled the persecutions.

The persecutions continued under Emperor Domitian when the Christians refused to worship the Roman gods or even recognize that the other gods might exist. For these early Christians, Jesus Christ was the Son of God; and the Triune God, of whom Christ was a person, was the one and only God. Since several of the emperors were deified by senate resolutions or self proclamations, worship practices of the Christians were also interpreted as treasonous. St. John was banished to Patmos and Timothy died in the Domitian persecution. Emperor Trajan in A.D. 108 began the persecutions again during which Ignatius, a student of St. John, was killed.

Persecution again surged under Marcus Aurelius, the emperor Galen served. Polycarp, Christian Bishop of Smyrna, sang praises to God as he burned at the stake. Tradition claims he was not consumed by the flames while some of his executioners were overcome with the heat. Roman soldiers severed his body a multitude of times with their

spears until his blood quenched the fire. Details and even the authenticity of the miracles reported about the martyrs is unimportant. What matters is the loyalty of our Lord to them in all their suffering. Jesus had died for their sins. The Lord brought them to the Christian faith and kept them steadfast in that faith. For that love, the martyrs, with strength and power from their Lord, could sing praises in the face of death knowing that in death they had everlasting life in heaven. They knew that very unscientific idea as factual. Their lives and death testified to that fact.

What were the Christian beliefs about nature and their understanding of science? During the two centuries of the Roman peace, the Christians were simply too busy to concern themselves with human interpretations of nature which their Lord had created. They believed God was directly involved with steering all things in nature. Their Lord Jesus had come as their Brother, performing miracles in which even the wind and the sea obeyed Him. Facing persecution for their belief in Him had not permitted time for pursuing laws of science. With God intimately involved with all things, there was no need for laws that were independent from God's deeds. When Christian scholars tried to reflect intellectually, they concentrated on the Scriptures, the New Testament writings, and the rediscovery of the testimony of the Old Testament to the coming of Christ. The early church writers after St. Paul and St. John turned to allegory, describing one thing under the image of another in all their interpretations of Scripture. Such allegorizing indeed took its toll in the later centuries as church officials reinterpreted the clear words of the Bible for the common worshipers who had looked literally to their brother Jesus. A Christian writer in the scientific center of Alexandria, through allegorizing eyes, saw the world as the tabernacle and its furniture. The table of shewbread ("bread of the Presence," Ex. 25:23-30, NIV) standing on the north side of the sanctuary linked with the golden candlesticks and its seven lamps to the south of the sanctuary was like the seven planets in the southern sky. The two cherubim of gold which stood on the mercy seat could also be seen in the two stellar bears of the northern sky or the hemispheres of either the sphere of stars or of the earth. The Ark of the Covenant itself was the eighth light, the eighth sphere, the dwelling place of God. Just how this is tied to nature is difficult to imagine. The trouble with wholesale allegorizing was that little knowledge from it could be certain. Allegory and observational science could not be supportive of each other. The Christian view of science with such blinders, excusable for the excitement of being so close to the Maker of nature, and excusable under the burden of torture, was an unreal picture. It was a return to Plato's abstract thinking, away from Aristotle's observational science.

The famous English writer and historian, Edward Gibbon, in 1776 identified the assassination of Emperor Pertinax by the honored Praetorian Guard and their selling of the next emperorship to the highest bidder, Senator Julian, in A.D. 195 as the start of the decline and fall of the Roman Empire. Not only did outside invasions on nearly all frontiers still remain a constant burden, but such actions by the most trustworthy men of the army spawned internal revolutions. Abandoning the field and marching to Rome with his Pannonian Legions, Severus claimed the throne for himself, beheaded Julian, ordered the death of those immediately involved with the assassination of Pertinax, and banished the remaining Praetorian Guard from Rome. With the armies out of Rome, the city was vulnerable to the invading hordes of Northern Europe.

All the trouble that would come to Rome--invasion, revolution, natural disasters--was blamed on the so-called unpatriotic Christians. They remained obstinate, not recognizing anyone else's god as real. The Roman gods were imagined as angry and nothing good could be restored in the empire until the Christians were made to bow before the Roman gods. Although Emperor Severus had been cured of a severe illness by a Christian physician and Christianity had become acceptable to him, pressure from every political sector forced the Roman Emperor to order the persecution of the Christians who by this

time had grown large in number. This persecution was carried out in far spread regions of the entire empire. Persecutions waxed and waned with little Christians could do except testify of their faith and die under emperors such as Maximinus in A.D. 235, Decius in A.D. 249, Valerian in A.D. 257, Aurelian in A.D. 274, and the duel emperors Diocletian and Maximian in A.D. 286 and again in A.D. 303.

It was not until Constantine, an emperor with strong sympathetic leanings toward Christianity took over in Rome in A.D. 324 that Christians could feel free to worship without fear of losing their lives. In the famous Edict of Milan, in an effort to unify an empire greatly divided, the Christians were granted all civil and religious rights, permitted places for worship, and given back public lands which had been confiscated. At that time the organized Christian church was administered by one thousand bishops in Greek provinces and eight hundred bishops in Latin provinces. In spite of persecution, the Christian church had become large and prosperous. After Emperor Constantine the church gained political power as well.

Being legal did not solve problems of persecution for the Christians. Until they themselves learned forgiveness and tolerance, that Jesus Christ had died for all mankind, that God desired all people to be saved, that the Holy Spirit calls, gathers, enlightens, and sanctifies the whole Christian Church and not political powers, peaceful worship of their Lord would not occur. Barely did the Roman persecutions end when the Arian persecutions began. The debate over the deity of Jesus Christ raged but with physical torturous atrocities on both sides. Such harmful actions cannot be spoken well of. The question of the deity of Jesus truly is a vital one and worthy of all the debate that needed to take place for nearly three hundred more years with the surrender of reason to faith documented in the Athanasian Creed, but should not have provoked tortures and atrocities.

Lactantius, a Christian author writing between A.D. 302 - 323 in the freedom of the enlarged and protected Christian church, turned his intellectual ability toward nature. Guided by allegory and rightfully fearful of pagans, he wrote on the false wisdom of the philosophers. Not only did Christians still politically fear the pagans, they also feared the pagans' teachings. It must be remembered the original Greek philosophers of science rejected the gods. To the Christians, who had the very letters of men who witnessed the God-Man walking among them performing miracles and controlling wind and wave, sciences of eternal atoms without cause or elements transforming by themselves according to natural laws were a denial of the only true Triune God. They were willing to be torn limb from limb for such beliefs in their God. A science which described nature being moved by a primary mover that does not move or a god untouchable above the distant sphere of stars was false. Angels led these Christians through their ordeal and Jesus was there to greet them on the other side of death. Greek and Roman science was thus rejected by these early Christians. In ON THE FALSE WISDOM OF THE PHILOSOPHER Lactantius ridiculed the sphericity of the earth and rejected the existence of antipodes as an unknown race of people. His ridicule takes the form of imagining people with feet above their heads and the absurdity of snow and rain falling upwards. Ambrose of Miletus had no use for knowledge of the five elements and insisted that there was no value in knowing the position of the earth in the cosmos.

In A.D. 375, unpredictably and with incredible speed, an unknown race of people, the Huns of Mongolian origin, swept westward into and across Europe coming from far central Asia. The Huns sent the Goths of Germany streaming across the Rhine and Danube Rivers into Roman territory because the Goths had less fear of a divided and weakened Roman Empire than they did for the Huns. In a battle that followed at Hadrianople in A.D. 378, while attempting to hold back the Germans, the Emperor Valens was wounded and

then burned to death in a house used for a battle hospital. It gave the Goths a view of just how vincible the Romans were. The empire had been divided administratively between Diocletian and Maximian a century before, but Constantine and his ancestral line of emperors managed to rule the entire empire from Constantinople. With the Goths and Visigoths unchecked, the division of the empire was made permanent leaving Arcadius at Constantinople as ruler of the Eastern Roman Empire at age eighteen. His brother Honorius at age eleven was hailed as Emperor of the Western Roman Empire in Rome. The political instability of such young emperors led to internal revolution at the same time as there were massive invasions of all borders and this did not bid well for the empires.

In Alexandria, some distance from the turmoil, the Christians had enjoyed a generation of peace as a physical church body. The Bishop of Alexandria, Theophilos, ordered the destruction of the famous library and museum which by that time was no longer a leading institution of research and discovery. Ptolemy had been the last famous scholar to take advantage of the magnificent observatory with its precision instruments and the irreplaceable library collection. To the Christians at that time, a library that focused attention on interpretations of nature separate from their Lord's Word had no place in the church's realm. They felt nothing useful could be gained from such pagan writings.

In A.D. 410 the German Goths led by Alaric sacked the empire's western capitol, Rome. Five years later Christian mobs were doing the same thing in Alexandria attacking pagan philosophy. An uncontrolled Christian mob murdered Hypatia, the daughter of the astronomer Theon. St. Jerome during these years wrote with violent passion against the pagan philosophers and identified Jerusalem as the navel of the earth, thereby encouraging map makers to distort their maps to satisfy religious convictions.

The western empire simply was overrun by Germans. With weak leadership from the Roman government and the inability to raise taxes for the support of a dedicated army, the Germans could invade, roam, plunder, and settle at will. In their plundering and roaming about, they readily accepted Christianity as they made longer lasting contact with the people. In A.D. 476 a German general, Odoacer, declared himself King of Italy and banished the standing western emperor Augustulus, a young lad fifteen years old, a true symbol of the weakness of the Roman Imperial Palace. The Roman Bishop, the Pope, had more political power than the Imperial Palace and as a result a new problem emerged for the Christians.

In the east a pagan scholar of science wrote "Eighteen Arguments Against the Christian" in which he made extensive use of the doctrine of the eternity of substance, the central and most important law of conservation of matter which is still so important in our own time. He used this law as a refutation of the Christian doctrine of creation, particularly against creation from nothing. A Christian, John Philoponus from Alexandria, responded with exhaustive writings, in particular one set of seven books treating the six days of creation. He employed both the writings of Holy Scripture and Aristotle, bringing together a vast knowledge of natural science, the need to restore science to its real observable state, the need for efficient and final causes, and the need to recognize the true God of Creation. This was a most proper approach to the understanding of nature where our Lord does not give us the details but instead from the time of creation gave the command to subdue the earth and rule over it.

At the Academy in Athens, Simplicius, a commentator on Aristotle and a pagan defender of the old school of science, responded against Philoponus and against the Christian belief of creation from nothing. The Christian Emperor of the Eastern Roman Empire from Constantinople ended the debate with a decree in A.D. 529 which closed the Academy at Athens and sent Simplicius and many other scientific scholars from this ancient school

fleeing for their lives to academic freedom in Persia. Emperor Justinian had closed the Academy to stop what he called its pagan and perverse teachings. Greek science, which had begun by rejecting the Greek gods, developed into a system of thought describing nature moving by itself or by unchanging number gods or by an immovable god above the stars. Greek science ended an era by rejecting the Creator Himself. The Romans left such science unchanged. The early Christians threw such science out. Science as a human endeavor continued in Persia, later to be held hostage by the Muslims for another six hundred years. When the Christians would relearn what they had rejected, they would settle on who the one true God really was and would turn to the problems of just how He made nature and sustained it. Such a Christian change impressed on Greek science would recreate it as a new dynamic system of thought, opening up a wondrously marvelous scientific age unequaled and emerging as the scientific revolution.

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SEPARATE FROM HIS WORD

ARABIC SCIENCE: A Hostage under Muslim Teachings, Chapter 12

Mohammed was born in A.D. 570 in Mecca, a city at an oasis in Arabia. He was a camel driver and trainer from a very simple background with no formal education whatsoever. He was distressed in part over the bloody Christian Arian controversy, which for the true Christians was settled in the writing of the Nicene and Athanasian Creeds. These creeds reaffirmed the Scriptures declaring the one true God to be three Persons with the Son of God, Jesus, being one Person, with both a human nature and a divine nature, all beyond human understanding. These creeds Mohammed found unreasonable and rejected them. Mohammed also was troubled with the idolatry and immorality of his fellow Arabs and turned to the fabrication of his own religion. He claimed he was visited by the angel Gabriel and given the sacred writings, the KORAN. Mohammed copied what he could on scraps of parchment and dried camels' ribs and skins. Other parts of the KORAN, Mohammed claimed, were given to him by inspiration.

The entire KORAN, 114 suras, on first reading, appears as a collection of many short, scrambled, and confused writings. With imagination and intense study of the KORAN, structured and detailed teachings emerge that are well beyond the educational capabilities of Mohammed. The KORAN is also the only major book besides the Bible that claims for itself an origin of inspiration. Professor Siegbert Becker wrote of the KORAN:

"When we remember Paul's statement that the worship of the heathen is addressed to devils, we may well be moved to ask whether Mohammedanism is in reality only the invention of an uneducated camel driver." (S.W. Becker, WIZARDS THAT PEEP, p. 67, quoted with permission of the Northwestern Publishing House)

At a pastor's workshop studying WIZARDS THAT PEEP, Prof. Becker wondered out loud if Mohammed indeed did write from inspiration--inspiration of Satan. (Becker's Table Talk)

Mohammed became a fugitive teacher with his KORAN and faced persecution which forced him to flee from Mecca for his life on July 16, A.D. 622. In Islamic tradition this day is called the Hegira meaning flight and marks the first day of the Islamic calendar, from which all modern Muslim times are counted, so that A.D. 1995 is 1373 A.H. (After Hegira). In A.D. 630 Mohammed and his followers, in a brutal blood bath, reconquered Mecca and destroyed all idols except a large meteorite of black basalt found on the white desert sands. Today it is the Black Stone which is kissed by all who make an Islamic pilgrimage to the temple Kaaba where it is housed.

1. THE DOCTRINES OF ISLAM

Islam contains five doctrines. The first is the simple creed, "There is only one god and his name is Allah and Mohammed is his prophet." To the Muslims, Allah is all seeing, all knowing, and all powerful. The second doctrine is a belief in angels which identifies the chief angel as Gabriel, the fallen angel as Shaitan, and followers of the fallen angel are called djinn. The third doctrine identifies four books considered sacred by Muslims. The TORAH OF MOSES includes the first five books of the Bible and the ZABUR is a collection of the Psalms of David. Indeed, these are sacred books. They truly show the creation, the fall of Adam and Eve into sin, and provide the great promise of the Seed of a

woman. But Islam also identifies the INJIL, a book supposedly written by Jesus, as a sacred book. To the Muslims it is a an account of Jesus' life by Jesus himself which was not accurately described by Matthew, Mark, Luke, or John. The INJIL is a rejection of the Christian Bible, includes many inconsistencies, and has a late date of origin identifying it as a hoax. Although it existed at the time of the early Christian church, the INJIL was never accepted by the early Christians.

The fourth book called the KORAN, copied and written by Mohammed, is claimed to be the most sacred by Islam. It presents Allah's final word to mankind superseding all other writings. It is the KORAN that takes the Gospel which was truly given in the writings of Moses and David and accepted by Islam and turns the reader from Christ. The KORAN teaches that Jesus is not the Son of God and refuses the salvation freely given by His redemption. This is the satanically inspired teaching which sends all who follow Mohammed to hell. The KORAN teaches the virgin birth of Jesus to Mary, but as a special creation of Allah just as Adam was created. According to the KORAN Jesus was not conceived by the Holy Ghost. Mohammed's reasoning in the KORAN claims Allah is all powerful and for Allah to have a son would remove and cause a sharing of that power. Also Jesus did not die on the cross according to the KORAN. The Jews did not kill him or crucify him, but were deceived by Jesus' disciples. Some Islamic commentaries carry such teachings further claiming Judas was disguised as Jesus and handed over to the Jews and ended up being executed by crucifixion instead of Jesus. Jesus was then taken directly to heaven as a prophet of Allah without death. Islamic doctrine also teaches a list of twenty-eight prophets which included Adam, Enoch, Noah, Abraham, Ishmael, Esau, Jacob, Moses, David, Jonah, Elijah, Elisha, and Jesus. Mohammed was the chief prophet.

The fifth and final doctrine of Islam teaches a resurrection from the dead on the last day at which time Allah will send each person to heaven or hell as he pleases. By controlling all things, Allah's judgment is predestined in a complete reasoned sense in which he chooses whom he will take to heaven and also those whom he will send to hell. Even if a person desires to go to heaven and to do Allah's will, if Allah is against such a person, he will be led astray, even tricked into doing wrong. What a contrast with the true Word of God. "God our Savior . . . wants all men to be saved and to come to the knowledge of the truth." (I Timothy 2:3, 4) "For God so loved the world that he gave his one and only Son, that whoever believes in him shall not perish but have eternal life." (John 3:16 NIV)

Rejecting the Triune God, Islam replaces the redemption paid by the true Son of God with works of people called the Pillars of Faith. These works, which have nothing to do with faith, are rigid rules which all Muslims must keep. The Kalimah is a repetitious confession of the short Islamic creed. Five times a day at rigid prescribed times a Muslim must kneel and bow down toward Mecca. Alms for the Islamic church and the poor are required as strictly as taxes. The Ramadan is a required thirty days of fasting although many Muslims then feast every night. A pilgrimage to Mecca called the Hadj is required of all members of Islam once in a lifetime with absolutely no exceptions. However, it is possible to pay someone to make the pilgrimage as a substitute. Finally, since no good work is certain to please Allah, knowing he might deceive or trick an individual whom he is not pleased with, the Jihad or holy war in which a follower might die conquering lands for Allah was the only way to get Allah's attention and convince him on an individual's behalf to be worthy of heaven.

To any Muslim the Christian should use Moses and David to show them that the God of Abraham and Ishmael and Esau indeed had a Son and His name is Jesus. Jesus fulfilled all the prophecies in the books of Moses and David. Jesus and Jesus alone died on the cross for all mankind and says to all, "Come to me all you who are weary and burdened,

and I will give you rest." (Matt. 11:28, NIV) "I tell you the truth," Jesus answered, "before Abraham was born I am!" (John 8:58, NIV) "I and the Father are one." (John 10:30, NIV) "Anyone who has seen me has seen the Father." (John 14:9, NIV)

2. ISLAMIC CONQUESTS

Mohammedanism is a brutal work-righteous religion offering no comfort or certainty. Islam extracts high sacrifices from its people by rigid laws of behavior, even death, offering only a fatalistic acceptance of Allah's will. On the last day, when the true Son of God, and not Allah, appears to judge, the writings of Mohammed will be exposed for the satanic writings they really are. Until then, the Muslims, following these tragic lies of Satan and Mohammed, have been a people forcefully proselytizing all whom they conquer and dying for Allah, calling for his attention in a holy war. The Muslims quickly took Egypt, Palestine, and Syria from a feeble successor of the Eastern Roman Emperor Justinian. The Muslims crushed the Sassanian Kings of Persia in A.D. 640 just two years after Mohammed's death and pushed into Asia Minor to stand at the gates of New Rome, Constantinople, by A.D. 668.

Eastern Romans discovered naphtha, a liquid bitumen which burst into flames upon contact with air. This substance was extracted from oily ooze coming up from within the earth near regions where today oil wells are predominant. Sulfur and pitch from evergreen trees were mixed with the naphtha. This mixture readily ignited and when it did, a devastating explosion occurred, thick black smoke emerged, and near inextinguishable fires spread wherever the substance scattered in the explosion. The defenders of Constantinople used this mixture called Greek fire on missile rocks and at the end of arrows, javelins, and spears. Greek fire was also poured from large boilers around the walls of Constantinople. Fireships with missile launching machines propelled Greek fire everywhere against the invading Muslim navies. Greek fire and exceptionally severe winters repelled a six-year siege of Constantinople. A second siege of Constantinople was conducted by the Muslims thirty years later and was repelled again by Greek fire. After devastating losses of life suffered by the invading armies and navies, the Muslims had to be satisfied for a long time withdrawing from Asia Minor. Nevertheless, the Muslims continued the holy wars, swept across North Africa from Egypt, entered Spain by A.D. 711, and continued into France to be stopped by the Christians in the hard-fought Battle of Tours in A.D. 732.

A resurgence of the Muslims in the east cleared Syria of Christians by A.D. 1291, crossed the Dardanelles in A.D. 1451, and laid siege to Constantinople with a quarter of a million soldiers and an armada of seven hundred ships. Constantinople fell, and the last Eastern Roman Emperor was killed in A.D. 1453. This new Muslim threat of the Ottoman Empire continued pressure against eastern and southern Europe pushing into Hungary, invading Austria, and besieging Vienna in 1683. The fear of European Christians was aptly described by the reformer Martin Luther in a hymn written in 1541.

"Lord, keep us steadfast in Thy Word;
curb those who fain by craft and sword
would wrest the Kingdom from Thy Son
and set at naught all He hath done."

(THE LUTHERAN HYMNAL, #261, Reprinted by Permission, Concordia Publishing House)

However, in modern times it has been toned down by translators not seeing the same

threat. Luther, in the second line, prayed, "curb Pope and Turk whose craft and sword . . ."

3. ISLAMIC SCIENCE

During these Muslim conquests, the great Greek writings of science that survived the many Roman revolutions and the later Christian reactions of burning the pagan writings were preserved by the Islamic culture. This culture of holy wars, of strict obedience to behavioral laws, and an absolute fatalistic view of a world under Allah, put a heavy imprint on the captured scientific works. The Muslims, believing the KORAN held all the answers for all things, provided nothing new, and this was worse for science than the practical Roman imprint. There simply was no need to examine nature or give it a new interpretation from what was already written. Nature followed strict laws as Muslims did in obedience to Allah. Nature was unalterable and no appeal to an all knowing, all powerful Allah would change it. The rigid fixed laws were written in nature and never changed. Mankind was fatalistically preyed upon by nature.

In algebra, invented by Muslim Arabs, we can see the fixed rigidity. One and only one solution exists to an algebraic function. Although much could be gained scientifically with the new tool of algebra, the understanding of nature was limited by this rigid form of mathematics.

Greek astronomy was of great interest to the Muslims because of the unchanging characteristics of the celestial world of Aristotle. The concept of perfect circles from Plato and Aristotle and later the epicycles of Ptolemy likewise described an unalterable, fatalistic, and predictable starry heaven which was readily acceptable to Muslims. Understanding the motions of the stars and planets as perfect unalterable motions permitted the invention of the astrolabe, a two dimensional map of the heavens in which interlocking circles would be moved to show coordinating motions in the heavens.

In Baghdad, intellectual institutions always remained somewhat independent from the heavy imprint of Islam. They were spawned under Persian, non-Muslim influence with an influx of ideas from Athens after the Christian purge of pagan teachings. Alchemy of Persian birth followed Greek views of matter, that all things were made of the same four ingredients or elements--earth, fire, air, and water--in various mixtures. In addition to Greek understanding of matter, the Persian alchemist sought a different understanding of metals, once thought to be of the element water because of their liquid qualities. Gold was thought to be the noblest and purest of metals. The alchemists reasoned that a transformation from one metal into another metal must exist by mixtures and transformations of the elements. It was well known that bronze was formed from mixing liquid copper and tin. Harder brass was formed from mixing liquid copper and zinc; and hardened iron or steel was formed from carbon and liquid iron. The special transformation from base metals to noble metals, though never accomplished, was sought through a mixture of a base metal and a rare fifth element, elixir.

The special interests in metals caused a change in the basic definitions of what an element was and was not. Once metals were isolated as substances, not chemically but mentally, it was only a matter of time until the humanly invented classification of materials around four or five elements would collapse and even the observations would change to respond to the new definitions. Fundamental to scientific thought, in the struggle to understand nature, we see basic definitions being changed.

The first major classification break from the Greek elements was achieved by the Arab

alchemist, Jabir (A.D. 760 - 815), who maintained a laboratory at Kufa on the Tigris River near Baghdad. His classification of matter places all chemical substances into three categories--spirits, metals, and pulverizables--with metals as central to the system. He identified a hierarchy of seven perfect metals climbing a ladder of purity from Chinese iron (zinc) to iron to copper to tin to lead to silver to gold. Since all metals were isolated through the melting process, it became understandable that another family of chemical materials would be spirits, the substances that are consumed by the fire or formed into a nebulous gas. Some of these spirits were sulfur, mercury, camphor, and common air. Also central to isolating metals were the non-burnable, non-malleable materials leftover once all was burned and the metal was removed. These were the pulverizables such as salt crystals. Using this system it was not important if some materials were identified as a substance from water or if the materials gravitated or levitated to determine the content of air, fire, or earth. What became important to the alchemist was if it would burn, if it would be malleable, or if it would crack and be pulverized in a mortar by a pestle. These then were the tests for spirits, metals, and pulverizables, a new system of elements.

Science as a human endeavor was not an accumulation of more and more true knowledge. The five Pythagorean solids and the corresponding elements were irrelevant to the new alchemists even though they still talked and wrote about those elements. Observations and facts about substances changed with the new humanly invented classification. This valuable change by the Arabs and Persians gave a different definition for elements, gave different laboratory tools, and permitted a different way of looking at observations. However, no one recognized the value of such change until the discovery of oxygen by Lavoisier in A.D. 1789 (TRAITE' ELEMENTAIRE DE CHIMIE) and the reintroduction to the atomic theory by John Dalton (NEW SYSTEM OF CHEMICAL PHILOSOPHY) in A.D. 1808.

Another Islamic notable was Rhazes (A.D. 865 - 925), an alchemist and medical doctor in Baghdad. He brought together and invented many of the chemical tools found in a beginning chemistry course of today as well as invented a few instruments to fit the new system of chemical thought. His laboratory included things like crucibles, stills, ladles, scales, weights, flasks, sand baths, water baths, filters, kilns, funnels, mortars, and pestles. As a doctor of medicine, he wrote the first definitive work on smallpox and measles and a mammoth encyclopedia of the medical knowledge from the Greeks and other known sources of his day. Nothing new was added, but science in this manner, captive in Islam, was preserved. Diagrams or drawings of the human body as well as the detailed study of it were forbidden to the Muslim. Under such beliefs medical knowledge could not grow.

The most continuous record of the motions of the stars and the planets was made at Baghdad continuing the fine traditions of the former observatories at Athens and Alexandria. The carefully displayed clockwork of the universe confirmed the fateful control of the universe by Allah. An adjustment, however, had to be made by Al-Battani, an Arab astronomer from Baghdad, to the position of Ptolemy's equant to keep the heavens moving properly according to the ALMAGEST.

4. CHRISTIAN LIBERATION OF SCIENCE

The fury of the Islamic holy wars across Africa through Spain and into France finally was stopped by Charles the Hammer at the Battle of Tours in A.D. 732. The Christians then slowly, with large losses, pushed the Muslims back across the Pyrenees Mountains. Not until A.D. 1000 were Castile, Aragon, and Navarre liberated by the Christians. Toledo became Christian again in A.D. 1085. In A.D. 1492 King Ferdinand and Queen Isabella's

army laid siege to Granada, the last Muslim stronghold in western Europe. With this rejuvenated political strength of the Christian nations came new ideas when many of the ancient Greek works not known to the Latin scholars were found in the spoils taken from the Muslims.

Fresh ideas, new ways of looking at nature emerged in the freedom from persecution and the disappearance of the threat of conquest. The Christian worshiped the true Triune God whose Son, God Himself, became a real baby born from a real woman and laid in a manger among animals of the earth. This same Son of God as Son of Man died a real death and dramatically walked among His followers after His death before ascending into heaven. The Christian's true God was not an Aristotelian god far removed from the earth whose sole function while not moving was to move the sphere of stars. This true Triune God created the world, lived among the people of the world, and remains close to every person as He continually maintains His creation. He answers the prayers of the faithful who call upon Him as well as cares for the unbelievers.

The natural world given by such a God was real, not abstract as Platonic ideas and not symbolic allegory as wrongly thought by previous influential Christians. The natural world created and maintained by the true God was a dynamic, vibrant, changing, and living world. The new Christian scholar saw the world that way and invented the great intellectual tools to discover the structure of such a world. The Christian artist gave Western thought perspective permitting new views of nature. The Christian musician added brilliance and depth and dynamics to simple melodies, and the same was added to nature. Finally the Christian mathematician put together Greek geometry and Arabic algebra to give us analytic geometry and later fluxions or the calculus that permitted the exacting precision of description of every conceivable fluctuation. Science was freed from the fixed, rigid, fatalistic, unchanging laws of Allah. With their own tools and with the true Word of God, the Christians turned science into the most dynamic and exciting success story of the ages changing every Greek view. Science remained separate from His Word because it remained a human explanation. Nevertheless, mankind, using science along with His Word, accomplished much and a new scientific age was born.

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SEPARATE FROM HIS WORD

THE DISCOVERY OF CREATION:
The Beginning of Inductive Science, Chapter 13

Not all Christian leaders were violently opposed to the pagan understanding of nature. St. Augustine, who resided much of his life in North Africa in the Roman province of Numidia about a hundred miles east of the site of old Carthage, was one of these. He had been schooled in the knowledge of the pagans. He visited Rome and was a teacher of rhetoric in Milan before returning to his home province of Numidia. Augustine was converted to Christianity and wrote about A.D. 400 of his conversion and the great changes of his own world view in his famous book CONFESSIONS. It was St. Augustine who established a great formula for intellectual study for Christians, and it is shown in all of his writings as Bishop of Hippo. He wrote of how our Lord speaks to all people in two books. Those two books were the written revealed truths of Scripture and the revealed truths witnessed in nature. Both were true since both came from God Who is creator of all. Since God, in fact, created all things on earth, all things were good. Evil came from sinful man. The created things of God's earth were real, and in this sense, St. Augustine was a strong promoter of the real and true existence of what could be experienced by human senses. Such an approach was very open to the teachings of Aristotle whose doctrine of actuality had provided so much success to the development of science. St. Augustine's concept of two books of truth went a long way in overcoming the Christian mistrust of pagan science.

Emphasizing that great truths could be derived from human experience in nature and that these were given in the creative act of God, St. Augustine wrote a LITERAL COMMENTARY ON GENESIS. St. Augustine's interpretation of the creation account was literal only in the sense that it was a real creation. He interpreted the details given in the first chapter of GENESIS allegorically. Augustine wrote that the time God spent on creation was only an instant. At His command all of creation came into being in its full completion and in its perfect sinless state. The infinitely powerful Triune God could not be limited to the slow, restrictive process of six days for creation. The six days were pictures presented to the angels who were created before the earth was created. St. Augustine wrote that God desired the angels to comprehend that He was a God of order. To achieve that, God allegorically presented six separate views of the creation to the angels that they might comprehend at least six separate parts of the created order. The brilliant light of the day represented not real days, but God's almighty power and wisdom. The evening and the dim morning represented the weak and incomplete comprehension of the angels' understanding of what God had shown them.

The complex character of St. Augustine's thought is reflected in his adoption of Aristotle's principle of actuality meshed with his own view of a God-given real natural world alongside his allegorical view of the true Word of God. An allegorical view of reality supported Plato's ideals. With such allegorical views of the actual Word of God, a Platonic understanding of an ideal natural world prevailed over an Aristotelian understanding of an actual natural world. Science in this kind of Christian world view, although less antagonistic to the Christian, could not grow. Even as more and more Greek works through the centuries became available from the Christian reconquest of Islamic lands, observational demands of nature did not have to agree with an allegorical or ideal world view.

The Christian church during these centuries rightfully struggled with the understanding of their Triune God, an understanding to which St. Augustine gave a major contribution in

his fifteen books ON THE TRINITY. He wrote about a child trying to put the entire Mediterranean Sea into a small hole on a sandy beach. St. Augustine rightly concluded that the boy's efforts were analogous to trying to understand the Trinity with our small human brain. It seems that once a humble conclusion could be realized by the scholars of the Christian church, then they could direct their attention to problems closer to what could be observed.

Struggling with the interpretation of natural things, the Christians were cautious in their acceptance of pagan science, especially science as developed in Greek traditions. Knowing their Triune God controlled all things, they rejected all science which ignored God. When it came to working with nature as it impinged on their daily lives, these Christians, many of them Goths who readily converted to Christianity after overrunning the Roman frontiers, preferred older superstitions which came to be seen as miraculous workings of their Lord guiding them. When judgments between conflicting and especially accusing opinions became necessary in daily public life, rather than seek out facts of nature as a modern scientific society would, these seventh- and eighth-century Christians sought God's correct answer, not man's science which was separate from God. They turned to ordeals believing God would be with His own who were faithful to Him. Ordeals included water tests such as dunking a person in deep water to see if he or she would float or sink. Pagan science, such as that of Archimedes, taught that normal humans would float naturally without the influence of a god because their bodies are slightly less dense than water. The Christian, looking for his God's judgment, expected the innocent person to be identified as one that would sink. An innocent person was expected to withdraw a stone from a boiling vat of water with a bare hand without scalding the hand. It was expected that a person in God's favor could perform certain acts with fire or burning coals without burning ones own flesh.

Although such ordeals might quickly be condemned by the modern Christian, in the early centuries when ordeals were initiated by Christians, they were quite careful with the eighth commandment not to give false testimony against their neighbor, considerably more careful than we are today. Speaking well of their neighbor, they indeed desired to do their Lord's will. Ordeals gave way to an acceptance of science, but the Christians could become tolerant of science only when they could believe their Lord was behind science. Ordeals remained part of Christian practice, rising from time to time for many centuries in different communities that mistrusted human reason or scientific investigation, even coming to the New World in Massachusetts Colony as late as the seventeenth century.

1. ERIGENA

On the British Isles, Johannes Scotus Erigena (A.D. 815-877), an Irishman in the court of Charles the Bald, came to the conviction that true theology and true philosophy had to be the same. Working from Aristotle's primary mover that did not move, Erigena identified Him as the Triune God. Erigena, in an original ninth century work DE DIVISIONE NATURAE, described four forms of existence in which all things of the universe could be classified. The first form of existence was substance which creates and is not created. That was God Himself, an eternal being Who is the creator and source of all substance. A second form of existence was that which is created and creates. Erigena wrote that the existence of all things of the world had their origin in the eternal thoughts of God and came into existence when He created them. Some substances in turn transformed into other substances which was counted as a creation from something. The third form of existence was that which was created and could not create. This was most of the visible

world witnessed by human beings. With the fourth existence we come full circle back to God. Erigena identified this existence as that which is not created and does not create. In the Triune God, Erigena saw both the creator of all as the first existence and the final ender to all things as the fourth existence. The beginner and the ender, the Creator and the One Who does not create is the Triune God practicing His free will as God Almighty.

Actually Erigena's work displayed some unorthodox teaching with respect to the Trinity and God's knowledge of evil. Some of Erigena's forms of existence could also be interpreted as pantheistic, and after several centuries his writings were burned and he was declared a heretic. In England Erigena's ideas, which recognized God as creator and maintainer of all substances and forms of existence and giver of direction to material transformation, made a major impact for the Christian understanding of nature preparing for a new scientific age. The Creator-God had made all things real; thus Aristotle's doctrine of actuality became very acceptable. The Triune God took the place of Aristotle's primary mover. Different from Aristotle's god, the Christian's Triune God was an active God with total involvement. God created order. The study of nature was thus permissible to the Christian. It was a fine Christian thing to do to search for God's order. The concept of a God-given order for science was not utilized until the end of the twelfth century. When God's order was fully realized, it transformed all intellectual endeavors. The discovery of God's creation created modern science built on new methods of inductive reasoning.

2. THE NEW SCHOOL FOR INDUCTIVE REASONING

In the twelfth century, Europe was hard pressed on both its eastern and western sides by Muslim conquest. Although the Muslims were prevented from entering France, a power struggle for Spanish territory raged for several centuries. In England, responding to a new and major interest in learning by Christians, several schools or colleges already in existence banded together to form universities. Robert Grosseteste (A.D. 1168-1253), Bishop of Lincoln, became Master of the Oxford School and was given the title of Chancellor of Oxford. Impressive changes in English life were occurring everywhere with the invention of a harnessing collar for draught animals, the invention of water and wind driven mills, and the invention of bellows for metallurgists. These inventions brought wealth to both state and church, permitting generous support for the growth of the universities. Capitalizing on the rich times, Robert Grosseteste sought out special people for appointments to Oxford and in so doing, surrounded himself with men committed to inductive reasoning.

It must be remembered that Aristotle had written strongly against inductive reasoning, a system of logical steps arguing from a few particular observations concluding with a belief in a discovered general truth. The principle flaw rested on the knowledge that if a generalization was reasoned from a few observations, certainty could never be achieved. Other generalizations might be drawn from similar observations. Certainty could be achieved only if a general truth were known and particular truths were reasoned from them. Following the lead of Robert Grosseteste, a bold revolution occurred with the extensive use of inductive reasoning by the Oxford University faculty.

Grosseteste recognized Aristotle's 1500-year-old caution, but he reasoned that the God of creation had made all things with order and with purpose. God as creator and maintainer was the general truth and knowing that, Grosseteste could observe a few things in nature and by inductive reasoning, make concluding generalizations. Even though created order permitted inductive understanding, uncertainty remained. Many conclusions might be derived even from the same observations. The arbitration over

which generalization might be true occurred in the laboratory which was developed by Grosseteste. If nature could be controlled or forced to respond according to predictions from inductive reasoning, then those inductive conclusions must be correct. Aristotle's "demonstrations," or logical statements of a syllogistic argument by deduction gave way to the new method of thought at Oxford.

The demonstrations at Oxford were not mere worded statements, but physical laboratory demonstrations where materials of nature were used to demonstrate the reality of an explanation from theory. Laboratory demonstrations became a new method of proof, and experimental science was created. Today the major method of reasoning in all laboratory science is inductive reasoning. In the twentieth century a course of study is simply not science if it cannot be demonstrated in a laboratory. Scientific knowledge can grow with great speed when general conclusions about nature are reached from a small number of observations. This great achievement is a blessing given by our Lord to His believers who recognize that He gave order at creation.

Grosseteste's inductive methodology in the framework of Christian scholarship shows itself extended in the brilliant work of an Oxford scholar, Roger Bacon (A.D. 1214-1294), who studied at Oxford in the 1230's. Roger Bacon spent most of his years in Paris as a lecturer and a Franciscan monk. Although always a scholar, Roger Bacon was not well known until Pope Clement IV expressed interest in Bacon's writings in 1266. Bacon had not written much up until that time, and in order to provide something substantial for the Pope, he frantically began to write. Between 1266 and 1272, Roger Bacon produced more than eight major works, one of which was OPUS MAJUS written in 1268 as an encyclopedia pertaining to knowledge, its errors, its strengths, and its methods.

With the intellectual freedom given to a Christian, knowing his Savior and being set free from all bondage of sin, Roger Bacon recognized that perfect wisdom was found in the Holy Scriptures. He also believed as Erigena, that true philosophy from the pagans was that which could be demonstrated (Aristotle's syllogisms) by pure correct reason not in conflict with theology. To him, the purest form of such logic given by the almighty Creator was mathematics. Roger Bacon had the same unaltered confidence in numbers and thinking with numbers as did the Pythagoreans. When Roger Bacon fulfilled the rigid proofs of the discipline, he believed there could be absolutely no error in mathematics. Roger Bacon saw mathematics as errorless as the Pythagoreans thought their gods to be, but at this time in the history of scientific thought, Bacon knew the numbers were not gods. His Triune God governed the numbers in perfect order from creation.

Mathematics is especially important to science in the actual measuring and assigning of objective values to phenomena. Mathematics was the only tool able to overcome Platonic rejection of observations by human senses which Plato claimed were made bias by emotions. Numbers and their linkage with mathematics could be applied to nature to show change--a most valuable tool. Mathematics had always been used to show changes in astronomy, the ALMAGEST of Ptolemy being the most elaborate and successful example of this. Roger Bacon's contribution was to recognize the blessings of the true God in the gift of mathematics.

This new demand, to explain all the sciences with mathematics, raised the study of things in the natural world to a higher plane. No longer could a scholar rely on his own reason or on only arguments of other scholars. A complete explanation of natural things would require a mathematical explanation. Thus the great separation between the arts and sciences at the university began. How does one understand his or her world better--with the languages of literature and the arts, or with mathematics? For the natural sciences mathematics is recognized by Roger Bacon as the language of highest importance. It is

through the sweeping general truths of mathematics and the certain proofs, generally by deductive reasoning starting from general axioms and proving particular theorems, that the scientist can retain Aristotle's favored method for demonstration.

Roger Bacon also knew Aristotle's warning against inductive reasoning which Robert Grosseteste was promoting. The laboratory experiment became the main tool to overcome the limitations of inductive reasoning. Roger Bacon championed these laboratory methods insisting that only through laboratory experience, a new type of demonstration, could things in nature be understood. Logical explanations for nature could easily be arrived at, authorities could be quoted from a book, but the only way of understanding what really was going on was by demonstrating with physical means, not by words. Roger Bacon went further with the laboratory methods in science than the mere demonstrations of Grosseteste. Roger Bacon claimed the secrets of nature might be probed by examining nature in the controlled laboratory in ways not possible in the free and open natural world. Using the laboratory to test mathematical and physical predictions which assist in making a correct judgment for conflicting theories was also an expanded use for the laboratory in science proposed by Roger Bacon.

It must be remembered that laboratory science, the embodiment of inductive reasoning, was rejected by the Greek scientists trying to establish science separate from the influence of the gods. Now that Christians knew their God and that He created all order in nature, laboratory science became a logical extension of that knowledge. God created the order, and laboratory demonstration could reveal that order. To this end Roger Bacon dedicated laboratory science. Theology paved the way to the invention of laboratory science, and in turn, Roger Bacon believed discoveries from laboratory science would assist the understanding of the Scriptures. Nearly a thousand years earlier the Christians had killed and burned pagan scientists and their libraries and universities. With Roger Bacon, science and religion were in comfortable harmony and, in fact, more than that, the Christians were creating modern science.

Roger Bacon wrote about using science to show the unbeliever, who was not willing to listen to the truth of theology alone, his or her humble place amidst the great variety of life. He encouraged the use of demonstrable laboratory science to overcome illusions of magic and all sorts of blasphemous superstitions. Laboratory science was a welcome tool invented by the Christian for the Christian's use. Indeed it was more than an invention; it was a great gift from the Creator Himself.

These great innovations of science, presented by Roger Bacon, suddenly became suspect when Roger Bacon, given the opportunity to write to the Pope, made much of false translations of the Scripture and even accused the Dominicans of Paris of being the great corrupters of the biblical text. Perhaps he thought the Pope, placed in his position of authority through divine calling, would want to correct errors in the church. Instead, Roger Bacon's writings were condemned, he was imprisoned from 1277 to 1292, and he was left with only two years of his life as a free man. Such is often the way of a church body when its business becomes political and monetarily oriented. The leaders, held responsible by their God to keep His Word clear and true before His people, instead interpret all criticisms personally and seek to silence those who cross them in their ideas.

3. INDUCTIVE REASON WAS IMPEDED BY DOGMA

Innovation in science suffered more than Roger Bacon. The power of the papacy was growing like a rising flood, filling all the backwaters, taking control of every aspect of the Christian's life while the so-called servants of the Word, the leaders of the church,

followed obediently only what was decreed from the Roman headquarters. With no opposition to the rising flood of power, Pope Innocent IV summoned the first Council of Lyons in June of A.D. 1245 to consider problems developing between politics of the church and politics of the Empire. The western emperor Fredrick II was excommunicated and dethroned by the Pope who exercised the political power of the church above the state. In a second Council of Lyons in A.D. 1274 the eastern emperor Michael VIII acknowledged the supremacy of the Pope over the eastern church, and although such total control was never achieved, it does show that what was important to leaders of the church was power and not servitude to Christ Jesus and His brothers, the laity of the church. Authority was all that mattered.

Thomas Aquinas (A.D. 1225-1274) of the Dominican Order, a professor at the University of Paris, wrote commentaries on the many works of Aristotle as the proper authority for all knowledge of the natural world. In addition to these commentaries, in his two great works, SUMMA CONTRA GENTILES and SUMMA THEOLOGICA, Thomas Aquinas interwove the two great recognizable authorities of all knowledge. He merged the Holy Scriptures and the writings of Aristotle with the understanding that reason and faith can never be contradictory, especially when correctly interpreted by the proper authorities. Aquinas had achieved a peace between the pagan science of the past and Christian theology on the eve of a would-be new age of experimental science. Papal authority was becoming supreme, even over experience, and the new science of Grosseteste and Roger Bacon was not to be permitted its time for experimentation for another three centuries when the papal authority would finally be broken by Martin Luther. Science between 1250 and 1550 became confined to a book. The lecture hall replaced the laboratory and the library was filled with outdated books giving the authoritative answers about nature which were accepted as certain law.

4. INDUCTIVE UNCERTAINTY WITH RESPECT TO RAINBOWS

In fairness to Thomas Aquinas, the inductive reasoning approach of Robert Grosseteste and Roger Bacon was warned against by the authority of Aristotle which during their time was substantial. In fact, the laboratory experimental demonstrations did not eliminate the uncertainty which Aristotle warned about. We will examine a case study of the understanding of rainbows to show success as well as a lack of certainty for inductive reasoning, the mainstay of modern science.

The use of deductive reasoning with respect to rainbows and associated storm clouds in the open atmosphere is not possible. Inductive reasoning opens an entirely new realm of phenomena to reason. Robert Grosseteste began his studies of the rainbow by collecting all known accounts of when the color spectrum of the rainbow was visible. The color spectra were seen in rainbows. They were seen in the spray of water-mill wheels. They were seen in the spray of water made at the end of oars of row boats, and in the laboratory Grosseteste could produce color spectra on a wall screen by passing sunlight through spherical glass flasks filled with water. He concluded all drops of water or transparent spheres of any size filled with water refracted the light. Grosseteste also produced color spectra by passing white light through prisms and hexagonal crystals. These color spectra also were produced by refraction. Color spectra seen in iridescent peacock feathers were ruled out after determining they were produced by reflected light. Robert Grosseteste came to the inductive conclusion that white light, when refracted through a dense medium, weakened according to the angle through which the light was bent. The greater the bending, the darker the white light became, darkened from white to red to green to violet.

Climbing up into a cloud to measure cloud droplets and rain droplets was not possible, but in the laboratory Grosseteste could control the color spectrum, projecting it on a screen on a wall and sweeping it through a half circle arc as a rainbow. He thus concluded the droplets acted like prisms projecting the refracted colors on to the screen or wall of the next visible cloud and reflecting back to the observer on the ground below, just as in the laboratory (FIGURE 13.1). This was a marvelous conclusion, not possible without generalizing from a few particles carefully controlled in experiments. God gave order to all the world. If a few things could be understood and controlled in the laboratory, God's order would replicate itself everywhere in nature. But all possible observations could not be made. If one theory could provide an explanation based on a few observations, another theory might also be able to explain equally well similar although different observations.

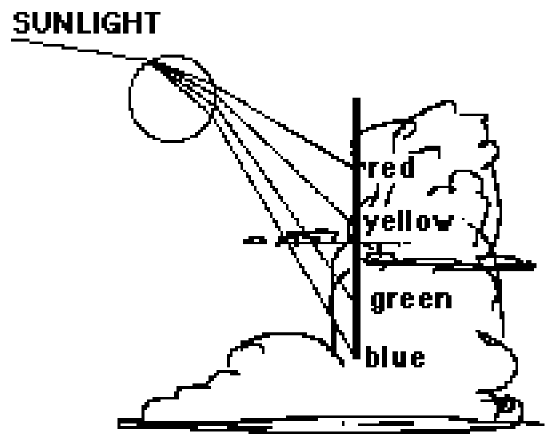

FIGURE 13.1 GROSSETESTE CONCLUDED REFRACTED LIGHT THROUGH RAINDROPS REFLECTED OFF A CLOUD ACTING AS A SCREEN.

Theodoric of Freiberg (A.D. 1250-1310) did just that. He rejected the thought that a whole system of individual rain drops would act collectively and project the rainbow on a distant cloud screen to be visible by all observers below. Instead, Theodoric developed a theory that explained white light entering many drops. Each individual drop let the white light enter it. As the white light entered a droplet, it refracted the same way as Grosseteste explained the darkening for larger refracted angles. These refracted rays then reflected off the back of the same drop. The color red was refracted the least so it had the largest angle of reflection. No screen was necessary. The color was seen in the back of the individual droplets (FIGURE 13.2). Since the reflected angle of the red color was the largest, only the highest droplets could be seen as red. Other droplets below would send their reflected red color to the ground, but it would not reach the observer and not be seen. Likewise a band of green droplets would be seen by the observer at an exact position, but nowhere else. Blue formed a band below the green. The result was that each observer saw his own rainbow and not the rainbow seen by the observer standing next to him. This explained why one could never reach the end of the rainbow. As the observer would move, he would see the rainbow in a different set of rain drops. The bow always centered on the observer and appeared to move with him.

This was an excellent theory for the rainbow, but it shows that Aristotle was correct about inductive reasoning. Alternative explanations for similar data are possible when one reasons from a few particulars and makes sweeping generalizations. This became a problem for science, but it was overcome by William of Ockham (died A.D. 1349) who argued that when facing several theoretical explanations of the same thing, the theory most likely correct is the one based on the fewest assumptions, on the one needing the

least logical statements. This became a great principle of economy of reason and took the name of "Ockham's razor." Theodoric's explanation thus is better since it needs no cloud screen. Each droplet performed all the needed functions of refraction and reflection.

Ockham's razor provided good logic down to our very day. Nevertheless, Ockham's razor is strictly a pragmatic rule. We have no certainty that the God of creation, in fact, made all of nature to operate with the least unalterable principles. Ockham's razor is a beautiful tool for the logic scholar, but when facing the real natural world, it remains unknown whether nature follows just a few principles or many different ones. Maybe nature even follows changing principles, although no person with scientific training would want to face that possibility.

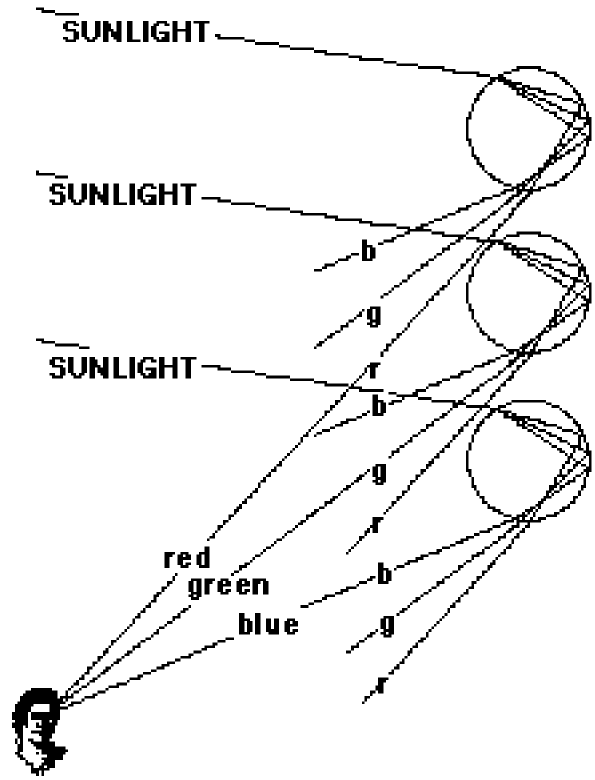

FIGURE 13.2 THE RAINBOW ACCORDING TO THEODORIC OF FREIBOURG IS SEEN AS BOTH REFRACTION AND REFLECTION IN THE RAINDROPS.

Aristotle's conclusion remained. No amount of observation can overcome the possibility of another theoretical explanation for a phenomenon of nature when building such theories from particulars by inductive reasoning. And Grosseteste's hope for experimental science did not overcome the objections raised in ANALYTICA POSTERIORA either. In our own time we see that very problem continuing with respect to the rainbow. Theodoric's explanation of the rainbow, refraction and reflection of colors in each drop, is the explanation in most modern school books. However, from the field of quantum physics it appears the rainbow may not be the result of optics at all. At best, the optical explanation may be only a superficial one. According to quantum physics, white light enters the rain drop, but a considerable amount of light enters the skin of the drop and is trapped circling the drop. As the angular momentum of photons increases beyond certain quantum levels, a quantum of energy is released at the quantum angles of 42 degrees and 50 degrees. This theory also explains the extra bright band within the primary bow and Alexander's dark band just on the outside of the primary bow, which optical refraction and reflection cannot do. Which is correct? Maybe the fourth or fifth theory not yet dreamed of is the correct one. That is the trouble Aristotle warned of.

Also efficient and final causes are missing in the explanation of the rainbow. Our Lord placed the rainbow in the clouds as a sign of His promise to maintain the seasons until Judgment Day and never again let the raging seas and rain cover all the land in a global flood. God's saving motive is a final cause which we can only as humble believers, yet

sinners, accept with thanksgiving and in faith. Again, without understanding such heavenly causes of the rainbow, the followers of Aristotle, as scientists, had to confess there still was much to understand about the rainbow.

Setting Aristotle's objection to inductive reasoning aside, it must be recognized that knowledge of nature by deductive reasoning simply could not grow with the speed inductive reasoning provided. The laboratory requirements did tie the imaginative theory to at least some observations of nature. They also wore down older laws of science that could not stand up to nature under such experimental scrutiny. Not even Aristotle's laws for nature survived, and they were founded on deductive reasoning. Such is the complexity of the natural world our Lord has made, and in these medieval centuries, no Christian expected reason or science to achieve a complete certain understanding of nature.

5. A LITERAL CREATION

The discovery of a literal creation in the book of GENESIS was a fourteenth century departure from the allegorical world of St. Augustine and his supporting philosopher, Plato, with his abstract ideas. The literal creation provided insights into science and at the same time allowed science its detailed interpretation of the real physical world. Under the allegorical and abstract paradigm for Scripture and science, strict adherence to experience and observation was not necessary. By the fourteenth century an allegiance to Aristotle's actuality and the knowledge of God as a God of real actual order emerged. Inductive reasoning and experimental methods of Grosseteste as well as rigid mathematical laws of Roger Bacon demanded perfect observable order. This time real experience and a literal interpretation of creation became a paradigm for human understanding. Science for many scholars was expected to fit in perfect harmony with Scripture.

Henry of Langenstein (died A.D. 1397) wrote such an encyclopedia of science within the framework of a commentary of the first several chapters of GENESIS, specifically the six creation days. His work certainly was not the first to treat science along with the creation week. LECTURAE SUPER GENESIM, however, appears to be the first work which stresses the reality of both science and the Bible. It is also one of the most exhaustive works, equivalent to more than 5000 typed pages with over a million words. From A.D. 1385-1393 Henry lectured at the University of Vienna on theology, harmonizing an encyclopedic understanding of science with creation.

Following Roger Bacon, Henry believed science could be used to enhance the understanding of Scripture, and Scripture could help to understand science. There was one and only one knowledge that was true. Henry also believed a person could understand things only through experience, by witnessing or by doing. In his lengthy lectures he used both the authority of Scripture and the authority of philosophers. He also used logical demonstrations. He expected symmetry in nature and argued on the basis of symmetry that all nature displayed God's handiwork. He argued from perfection knowing God created all things "very good." Henry believed the Christian received motivation for scientific research as a result of studying the biblical account of creation.

Henry, as a Christian, departed from the Greek scientists by accepting from the authority of Scripture that the Triune God, in fact, created all things from nothing giving all things a beginning and creating time in the process. Where St. Augustine saw a literal interpretation of the creation account limited only to the act of creation, that it was a real creation, Henry of Langenstein rejected St. Augustine's instantaneous creation and saw

the six days literally as real twenty-four-hour days showing God's work of creation. To create a real world required real time. Henry displayed his independence from Aristotle by arguing from Scripture that God created potentiality within matter at the creation of matter. Where Aristotle saw the efficient cause in the potential of nature itself (for example, a tree produced its own seeds), Henry pointed to the Creator as the efficient cause of the potential of the entire replication and reproduction process of all natural things. Although much of Aristotelian science was confirmed by Henry, it was a scientifically arrived at confirmation, not on an authoritative basis as that by Thomas Aquinas. This fresh, independent work shown in the LECTURAE SUPER GENESIM established the approach Christians, as scientists, would use proceeding with their scientific work. Natural reasons, not the miraculous, would generally be searched for, but all natural laws, all design seen in nature and all order subject to formulas, was placed in nature by the Creator at the Creator's will for the Creator's purposes.

For Henry, time was created by God with the first act of creating matter with all of the future creative potential within matter itself. From this initial incomplete creative beginning God's further work of creation added to and molded what He had made into the perfect world He willed. Henry's commentary on creation introduced many of the sciences right along with the creation account. Associated with the first day was perspective, a science of dimensions discovered and used especially by artists. While a mathematician with geometry saw a line as a mere humanly defined entity, Henry saw the line as a natural entity created in the initial act of creating mathematics with potential. The paths for rays of light were created to contain and direct the light once it was created.

Light itself, created the first day, was a perplexing substance capable of acting over a distance, traveling in real time with perhaps an immeasurable speed, nevertheless a real speed. Light traveled in created rays through a medium which could inhibit its motion. The medium itself accepted the light and could multiply the light sending it on farther and brighter. The medium could also absorb or diminish the light. Color was not light. One could bring into a dark room a brightly colored painted object and receive no illumination in the room. Only light could transform the medium in the room into a transparent medium which in turn then could permit colors to transmit and also be multiplied by the medium.

Henry viewed the second day of creation as the continued creative work of God in which He further formed His handiwork. "Let the firmament be made" was to Henry equivalent to "let the incorruptible orbs of the heavens be distinguished." (Steneck, page 56) The super-structure of the universe, the moving spheres that held the stars and planets of Aristotle's system, was created. The actual stars--the fixed stars and the wandering stars including the moon and the sun--would be added as the controllers of light on the fourth day. Aristotle's system was not seen as the complete correct solution. Henry had doubts about the existence of aether. He also believed the stars to be made of the same substances, the four elements, of which the earth was made. This conclusion, different than that which was possible under the Aristotelian gap of understanding between the terrestrial and celestial worlds, was reached as a logical result of the creation. With all matter created the same day, Henry reasoned the entire universe was made of the same substances, although their potential as separate substances with different purposes could be realized later in the week of creation.

On the third day, the matter created the first day was organized into the elemental spheres with the earth in the center of the universe resting there by the potential of gravity created within it. The element water, less dense, sat upon the earth. Some trouble existed since the earth's sphere, concentric with a water sphere, would be entirely submerged. Perfection demanded spherical shapes for both. Yet the Bible spoke of a separation of land and water. Henry's scientific solution explained a sponge-like earth

sphere eccentric from the water sphere exposing some land as the separation. Henry's exposed land mass was computed to be one seventh of the full surface of the earth sphere, quite different from the Ptolemaic geography. Henry's land mass of Asia, Europe, and Africa was the only land surrounded by water. Before sin no rugged mountains existed. Also on the third day, the air sphere and the fire sphere were created to levitate over land and sea.

With God's preparatory work of the first three days being complete, on the fourth day He began His finishing work. The stars and planets were added to their orbs. Henry recognized Aristotle's "primary mover that did not move" as the Triune God. From Him all things received their motion. Part of the finished created order was the creation of a "golden chain" of causes ultimately linked to God. God moved the sphere of stars. Each orb, an Aristotelian sphere, was moved by the sphere above and in turn moved the orb or sphere below. The "golden chain" controlled all things in nature as the moving parts of a mechanical clock. To Henry, however, God was more than a clockmaker who made the clock apart from himself. God indeed made nature apart from Himself, but He remained among all the parts maintaining perfect order which clockmakers could not do.

More completed work of creation by the Triune God was seen on days five and six. For these days, Henry taught the commonly accepted science, that angels and demons were the creatures of the fire sphere, birds and insects the creatures of the air sphere, fish and sea monsters the creatures of the water, and animals and man the creatures of the earth. Henry also experienced his doubts. He doubted that anything lived in fire or that any creature could be sustained on a single element as was also commonly believed. Henry knew most creatures were made of the several elements and would need food nourishment also of many elements.

Henry believed all living creatures had souls but differing levels of souls. The first level of soul was to be alive, to have vegetative power to grow and reproduce. The second level of soul included the ability to have sense, to know what exists around the sensing organism. A third level of soul was to have desire and appetite. The fourth level of soul permitted motion to satisfy that desire and appetite at will, and the highest level of soul was the ability to think. Such a system could readily be used as a classification of living creatures. Henry also gave other classification systems which were all different than the ladder of nature of Aristotle. One classification system was based on motions of the creatures; another system was based on the organisms' methods of reproduction; another system used the sensing ability of creatures for distinguishing characteristics; and yet another system used the presence or absence of vital organs of the creatures. Henry insisted any classification system used must show a hierarchical structure toward man as the Creator's design. Which classification system was the best? Henry did not choose. He simply enjoyed the tour of God's museum. In Henry's encyclopedic work the chief motive for science always was for a better understanding of the Creator, not the creation itself.

What must not be lost in the excitement of the new Christian embrace of scientific knowledge is that although science by Henry of Langenstein, Roger Bacon, and Robert Grosseteste agreed with the Scriptures, the origins of the scientific interpretations were still separate from His Word. Inductive reasoning, encouraged by the view that God the Creator was a God of order, sped the growth of scientific knowledge, but Aristotle's challenge to inductive reasoning still remained. Authority demanded by Thomas Aquinas kept false ideas alive for centuries. Finally, the mathematical models of nature required by Roger Bacon, which could indeed describe nature, could not be demonstrated with certainty. Unanswered was the question of whether or not simple agreement with nature, in fact, meant that nature followed mathematics.

Still, the gift of inductive reasoning, experimental science, enhanced in the light of our Lord's creation was a true gift. "Fear the Lord, you his saints, for those who fear him lack nothing." (Ps 34:1, NIV) The Christian who turned to his Lord for direction was blessed in spite of warnings from pagan logic. That has always been the case. Jacob made white striped wood and placed it in front of his flock, and God blessed him with streaked or speckled sheep. When interpretations of dreams were important, Daniel was given the ability to interpret. The disciples found their Savior in spite of the condemnation of the high priests. When allegory was valued, St. Augustine found the one true God. Grosseteste could touch his Lord's creation in experiments. Roger Bacon saw his Lord's perfect order in mathematics even as Henry of Langenstein felt the fire of excitement in his soul studying the creative works of God. As a modern quantum physicist facing creations and annihilations of subatomic particles comes to his Lord in humility, he will know from the Scripture who is the Creator, the Redeemer, and the Sanctifier. ". . . and I have filled him [Bezalel] with the Spirit of God, with skill, ability and knowledge in all kinds of crafts . . . . Also I have given skill to all the craftsmen to make everything I have commanded You." (Ex 31:3,6, NIV)

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SEPARATE FROM HIS WORD

A NEW WORLD, A RENEWED FAITH, AND A NEW SCIENCE: Columbus, Luther, and Magellan, Chapter 14

Nothing stabilized the laws of science more firmly than the doctrines of the church which Thomas Aquinas had woven together with ideas of men. Aristotelian science became equivalent to the Word of God with experiment being tested by authority. Aristotle knew the oceans were the lowest place to which water could gravitate, but ocean water was the impure mixture of water with other elements. For Aristotle, the source of water always was the sphere of pure water above the atmosphere, but this sphere was lost in the Middle Ages. Water in the Middle Ages was subject to gravitation alone and not to levitation. From Aristotle, it was certain that wind was not moving air, but was air that was pouring out of "air springs" in the earth. The naval spirit of the ancient Phoenician and Greek was gone. The scientific dogma of a medieval Aristotelian view saw these "air springs" confined to the land mass. Thus, sailing far out of sight from land had no practical purpose, in fact, could be dangerous. It was believed that if one would sail too far off the coast into oceanic regions of no wind, a sailing ship could be entrapped. According to the authority of Aristotle, the oceans were like the Mediterranean Sea without a current. Furthermore, Ptolemy's map (FIGURE 11.3), trusted by the sailor more than the Christian-produced maps, showed the Indian Ocean as a closed sea. The Atlantic Ocean bounded by Europe, Asia, and Africa, with a westward extended African coastline across the southern latitudes, was a closed sea as well. A stagnant, currentless, windless ocean was a barrier to the medieval sailor.

Marco Polo had traveled extensively (A.D. 1271-1295) to Asia first over land. He even worked in a high government position for Kublai Khan, an emperor of large parts of modern China and other lands reaching as far east and south as Cochin China (Vietnam). The travels of Marco Polo were recorded by Rusticiano when both men were imprisoned during a military skirmish between the cities of Venice and Genoa in A.D. 1298. Marco Polo's travels and Kublai Khan's interest in the west opened a land route of trade and intellectual exchanges between Europe and China.

The map of Asia for the European emerged from these travels, placing eastern China 180 degrees of longitude east of Poland. Through his travels, Marco Polo came into contact with a separate race of Asians on a great island nation still farther east of China called Cipangu (Japan). Marco Polo on one of his journeys east returned by sea experiencing great hazards, was detained by different coastal peoples of Sumatra and India, and suffered poor health. His story did not speak well of the sea route to the east across the Indian Ocean. With bitter wars going on between Muslims and Christians, naval travel was nearly impossible anyway. Europe traded with China and mapped the world by land.

The great Chinese rebellion beginning the Ming dynasty ended Chinese interest in any other part of the world except their own land. Foreign devils were quickly eliminated and the land route to the east was closed in A.D. 1368. Europe had become addicted to the spices and other products of the east and turned to the sea route through the Mediterranean. The new route crossed Egypt, went through the Red Sea, and across the Indian Ocean to the East Indies. But a resurgence of the Muslim power pushed the Christians out of Syria and all the way west to Constantinople, laying siege to the last vestiges of the old Eastern Roman Empire in A.D. 1453. Thus, for all of the fifteenth century, Europe was cut off from the far east and sought new routes by sea.

According to the detailed trusted maps of Ptolemy and the established laws of science from Aristotle, such a route was not possible. The Atlantic Ocean, without wind or current, was too large a barrier, and there was no sea route around Africa. The fanciful Christian maps with Jerusalem at the center gave varied answers. Some Christian maps followed Ptolemy showing greater amounts of land than water and were supported with holy symbolic numbers. The ratio of land to water was six of land to one of water. They based these numbers on the six days of creation and a day of rest. Others, like Henry of Langenstein in his calculations, claimed the holy symbolic numbers were reversed, six parts of water to one part of land. This water dominated view of the spherical earth saw all of the waters connected as one great ocean surrounding the land because of a literal interpretation that "all the waters were gathered at one place" on the third day. Christian scholars were most comfortable with a complete water hemisphere south of the equator since it solved the problem of a race of people in the southern temperate climate zone predicted by Greek geographers. If all races came from Adam and then again from Noah, they could not have gone to this southern temperate zone on the other side of the impassible hot equator. It was believed that races of Ethiopians were "burnt" black and the Vikings of the Arctic were "frozen" with extremely pale features. A total water hemisphere eliminated the thought of races of people other than those that were already known. Such geographical views gave hope to sailing around Africa if only the burning equator could be crossed.

The Christians of Europe also had many superstitions which they had absorbed from their pre-Christian cultural traditions. There existed stories about monsters, goblins, and demons which were neither officially accepted nor rejected. Tales of such creatures would come to the fore when men faced the unknown and fear permitted superstitions to become real. Dante's DIVINE COMEDY, published in the common Italian language at his death in A.D. 1321, did as much for the establishment of strange demons as Homer's ILLIAD and ODESSEY did for the establishment of the Greek gods. Merging together the commonly accepted pictures of Aristotle's universe with superstitions and with the teachings of the Catholic Church, Dante identified ten levels or concentric spheres of heaven and ten levels of hell down into the spherical earth with Satan encased in ice at the very center of the earth. The land mass was in the upper hemisphere of the earth centered on Jerusalem. All the lower hemisphere was water except for one island exactly on the opposite side of the earth from Jerusalem. That island was Mount Purgatory and was reached by Dante and Virgil, characters in the first book of THE DIVINE COMEDY, INFERNO, by traveling down through all the levels of hell and all their sublevels, climbing over Satan and then climbing back up within the other side of the earth through a long winding stairway. The picture of the world and the scientific speculation of a journey through the center of the earth are realistic in the context of Aristotelian gravitation. Dante's journey shows a good understanding of the sphericity of the earth. While THE DIVINE COMEDY gave a hopeful view toward a dream to sail around Africa, it also fortified the ideas about monsters and demons and gates of hell which hungry, scurvy-driven sailors might readily see anywhere in the mists at sea.

1. AROUND AFRICA

In Portugal, an Atlantic coastal nation, where tides oscillated high and low twice a day and contradicted Aristotle's concept of an unalterable level for the ocean, Prince Henry the Navigator was ready to challenge the known science of the sea. He had successfully conquered the North African coastal station Ceuta from the Muslims in 1415 and then set out to explore the west coast of Africa. He collected for his naval captains the best maps and navigation instruments available and planned a systematic exploration of the African coast that ended up lasting the remainder of the fifteenth century because fear of the

boiling hot seas and demons jinxing a trip slowed progress. Cape Bojador (bulging cape) at 26 degrees North Latitude on the coast of today's Spanish Sahara was a slight bulge seaward about one hundred miles north of the Tropic of Cancer. It was not a very prominent point, nor was it a dangerous point. Every sailor, however, knew it as the point beyond which you must never sail farther south. Beyond Cape Bojador it was believed that no people existed, terrible coastal currents pulled ships away never to return, and the sea became shallow and did not permit navigation without running aground and breaking up the ship. Between 1424 and 1434 Prince Henry the Navigator sent out fifteen expeditions, and all failed to go beyond Cape Bojador, so strong were the trusts in Ptolemaic maps, the knowledge from Aristotle of no winds at sea, and the traditions of superstitions.

In 1434 the first Portuguese ship commanded by Joao Dias sailed passed Cape Bojador, but progress along the coast remained slow. Always an expedition would leave Lisbon, cautiously approach Cape Bojador, run to the southernmost point of the last expedition, probe slightly farther south along the coast, and race back. There never was a fear of falling off the spherical globe. There was a real fear of boiling oceans at the equator which was somewhat supported with observable knowledge. The vast extent of the Sahara Desert was known. An extension of that desert came right to the coast of Spanish Sahara and Mauritania. It took ten more years for sailors to gain the confidence to proceed ten more degrees south and to first reach the Senegal River in 1445. Cape Verde (Portuguese for green), the westernmost point of Africa, sticks out into the Atlantic Ocean with thick green fruitful trees, well within the tropical zone and not a desolate burned coast. This beautifully created cape gave inspiration to many Portuguese expeditions who followed after the discovery of Cape Verde by Captain Dinis Dias. The special emphasis on the name "green" for this cape, amended on all maps drawn with monetary support from Prince Henry the Navigator, provided encouragement to new ideas that claimed the boiling oceans of the tropics probably did not exist. The very next year, 1446, Alvaro Fernandes sailed as far south as Sierra Leone. With the death of Prince Henry the Navigator in 1460, interest beyond the Gulf of Guinea waned. Portugal became a wealthy nation in Europe bringing sugar, wine, gold, and slaves to Europe. Bitter competition developed with Spain. Coastal forts and defensive navies along with occupied naval stations had to be established to protect Portuguese interests in the Guinea trade.

Interest in further exploration came with the discovery of the Congo River, a main highway to the interior of all of Central Africa, by Diogo Cao in 1482. He also pressed south to Cape Cross in 1486 at about 21 degrees South Latitude. Fear of the tropics was over. But the chief global map was still that of Ptolemy showing the south African coast curving westward closing a route to the Indian Ocean (FIGURE 11.3). King John II of Portugal paid Bartholomeu Dias six thousand reis in advance to continue exploring the African coast. Dias set sail with two sixty ton caravels and one store ship. The store ship represented a new dimension in exploration by giving the small fleet a much longer range with extra food and fresh water. Sailing beyond Cape Cross, Dias erected a pillar near what today is called Hottentot Bay at 26 degrees 38 minutes of arc South Latitude. The records are unclear if he intended to return to Lisbon or continue to explore, but a storm from the south with heavy winds turning from the north, as had rarely been witnessed, drove Dias southward for thirteen days into uncharted and swelled seas. After the storm Dias sailed straight east knowing by Ptolemy's map that he would run into land, but after several days of cold and heavy seas no land was found. He returned northward sailing more than 450 miles indicating that he may have been as far south as 42 degrees South Latitude. Land was sighted on the port side of the ship, Mossel Bay, on February 3, 1488. Bartholomeu Dias convinced his officers and crew to continue coastal exploration around the south east African coast slightly northward to the Great Fish River. It was obvious by that point that they had rounded the continent of Africa. There was, in fact, a large open waterway to the

Indian Ocean. Ptolemy's trusted map was wrong. Prince Henry the Navigator's hope had been realized. Christian Europe could now sail unmolested around the Muslims to the Spice Islands of the Far East. Great fleets would soon follow.

On the return trip Bartholomeu Dias saw the inspiring Table Mountain with its high cliffs descending to sea level with a magnificent harbor protected by a peninsula projecting out to sea. Dias named it Cabo Tormentoso or Cape of Storms. King John II realized the full political ramifications of reaching Asia and renamed it Cape of Good Hope. Dias returned to Lisbon to a world with a different map in December 1488. Waiting for his return was Christopher Columbus, trying to arrange a different voyage with hoped-for funds from King John II. With Dias' certain success there was no Portuguese interest for funding a sailing expedition west.

2. DISCOVERING THE OTHER DIRECTION

With Portugal controlling the sea to the south and around Africa, when Spain would awaken to its own sea power potential, it would look westward. An Italian, Christopher Columbus, would lead the way to the east by sailing west on a spherical globe across the Ocean Sea. Never was there a concern by scholars, political people in authority, or sailors that the world was flat or that by sailing west one could fall off the globe. As an example of the common beliefs about the earth, Dante's THE DIVINE COMEDY in plain Italian had displayed a very correct, although Aristotelian, view of the earth as a sphere, even to the reversal of the direction of gravitation on the other side of the sphere. The general acceptance of the spherical shape of the earth is witnessed when once the decision to sail was made, the fleet of three ships boldly shot across the Atlantic to the West Indies. There was no fear sailing west staying primarily in the temperate climatic zone as there was sailing south across boiling oceans of the burning tropics.

However, a great deal of uncertainty existed in the voyage west. From science it was known that no sea currents and no wind existed in the open ocean far from land. In fact, sailors had encountered the windless seas or the doldrums many times before. The most vehement debate struggled with the size of the earth and therefore the westward extent of the Ocean Sea. Those who wrote commentaries on Aristotle's works argued for an earth circumference of 40,000 miles. Eratosthenes' measurement argued for 25,000 miles, and Ptolemy had reported an 18,000 mile circumference. (Today the accepted mean circumference of the earth is 24,881 miles.)

Ptolemy's map put the Ganges River at 145 degrees East Longitude, the Magnus Sea (probably the South China Sea) at 170 degrees East Longitude, and the sea port Catigara (unknown today) at 180 degrees Longitude 10 degrees South Latitude. Catigara may have been any one of the passages through modern day Indonesia such as the Strait of Malacca or the Selat Sunda. This put China six thousand miles farther east than today's map. The travels of Marco Polo gave exaggerated distances placing China much farther around the world eastward than the maps of Ptolemy. When Cipangu, with its many islands eastward beyond China was added, it was placed even closer to Europe and perhaps only 1800 miles from Spain. It was this favorable distance Columbus argued for.

King John II of Portugal, having the certain route around Africa under his control, was uninterested in an unproven adventure. The earth's circumference according to Eratosthenes would make the Ocean Sea 9,000 miles wide and according to Aristotle, the authoritative source, 24,000 miles wide. That such a journey theoretically could be done was never doubted, but the long distances without fresh food and fresh water or a land port for rest made the thought impractical and too costly.

King Ferdinand of Spain, having spent much of the national wealth driving the Muslims from his country, preferred to listen to his more conservative advisors. On January 2, 1492, Granada fell. The Muslims were expelled and Spain could be more generous. August 3, 1492, Christopher Columbus sailed with the high tide from Cadiz at the same time as many other ships set sail crammed with Jews expelled from Spain. Columbus sailed with some scientific evidence in his favor since Ptolemy was the authority sailors trusted. In a previous voyage to the Azores, Columbus had learned that several bodies of darker skinned people were washed up on shore in a violent storm (an Atlantic hurricane). Immediately Columbus interpreted the race of these men to be Asian thinking that they probably were from islands not far from Cipangu and also not far from the Azores and confirming his idea that the Ocean Sea was not very wide. Leaving Cadiz, Columbus sailed south to the Canary Islands as a shakedown cruise for his fleet. Confident of his equipment and crew, Columbus sailed straight westward departing the Canary Islands September 8, 1492.

The wind remained steadfast from the east, never changing. The unchanging winds are what led to near mutiny, not for fear of falling off the earth but for a true fear that the ocean might be larger than Admiral Columbus thought. In a square rigged ship, such as the SANTA MARIA, the NINA, or the PINTA, running before the wind was maximum efficiency, but tacking against the wind, sailing a zigzag path across the wind to always catch an angle whereby the wind could push the ship, was very inefficient and took many times longer to travel a given distance. Wind in uncharted waters was uncertain. When it was found that the wind was always strong, that was a discovery different from Aristotle's teachings about wind at sea. When the direction did not change, that meant many days of hard sailing against the wind on the return trip for every day of sailing with the wind.

Fresh water and fresh food diminished. Columbus started to keep two logs, one for his officers and one for a true, but secret record for himself, always cheating on the distance traveled to give false information as to how far west they had come. October 12, 1492, after thirty-four days of running with the wind, land of the island of San Salvador was sighted. They had come a real 2100 miles.

After resupplying their ships and mapping many islands southeastward to Hispaniola, Columbus set sail on January 16, 1493, returning to Spain by a route about ten degrees farther north. To the amazement of the sailors the wind was continually from the west. Columbus certainly had not proved the world was round. The ancient Greeks did that. All of Europe knew that. Though he thought he reached the outer islands of Cipangu, the East by going west, he had not achieved that by a long shot. Christopher Columbus had discovered the Trade Winds, a system of winds strengthening and widening over a large band of the tropical latitudes in the summer for the Northern Hemisphere. In the north in winter these easterly winds diminished in strength and narrowed in latitude moving closer to the equator. At the same time the polar region grew cold and the westerly winds were strengthened and pushed to the more southerly latitudes. By the grace of the Triune God, whom Christopher Columbus worshiped, a war with the Muslims and a depleted king's treasury could be seen as a delaying action for Columbus' welfare. His departure from the Canary Islands and his return from Hispaniola, guided by the grace of God, led him to discover this great circulatory wind system, a great hemispherical movement of air over the Atlantic Ocean, on the first run to sea without a mishap. This system would be the major trade route as long as sails were raised from ships--to the New World in spring or summer when the easterly winds are strong and to Europe in autumn or winter when the westerlies blow.

The Pope, exercising his authority over all matters both spiritual and temporal and

especially exerting that authority over the newly accepted reality of antipode races, immediately drafted a papal bull giving Portugal the right to shipping routes to Asia and new lands and peoples going eastward and to Spain the same privileges sailing westward. Details were worked out in the Treaty of Tordesillas of 1494. A line of demarcation was drawn on a globe from the North Pole to the South Pole along the meridian 370 leagues west of the Cape Verde Islands, at about 46 degrees West Longitude. All new lands belonged to Christendom headed by the Pope and were given to others for administrative purposes. Portugal received all new lands east of the line of demarcation, and Spain received all new lands west of the line of demarcation. The division of the entire world in this manner signified the certainty all scholars and politicians had that the two new routes to the east circumnavigated the Muslims. Vasco da Gama would not reach the east going around the Cape of Good Hope until 1498 when he entered the port at Calicut, India. Ferdinand Magellan would reach the Philippines in 1521 by sailing west. Dividing the world in this manner also showed the total lack of understanding by all that San Salvador and Hispanoila were not in Asia.

3. DISCOVERING AMERICA

It took a scientific interpretation of the observed data together with the known map, Ptolemy's map, to discover the New World. Amerigo Vespucci, born in Florence, became a commercial businessman outfitting ships as a trade and studied astronomy and geography as an avocation. Columbus' third expedition had failed to discover a route to India. Amerigo Vespucci was interested in the careful study of map-making with a mathematical approach invented by Ptolemy, who used astronomy to pinpoint exact positions on a globe, and developed an incentive to establish his own expedition. Catigara was the easternmost port on Ptolemy's map at about 10 degrees South Latitude. Passage through East Asia, he thought, must be near this latitude. Vespucci joined an expedition led by Alonso de Ojeda to the West Indies in 1499 and explored about 1200 miles of what was believed to be mainland Asia from Trinidad to nearly the mouth of the Amazon River. He was struck by the vast populations of people living in the tropical zone, Ptolemy's forbidden zone. Vespucci also struggled with a new method to measure longitude based on mathematical astronomy rather than dead reckoning which used compass readings, inaccurate estimates of speed and course direction, and very crude measurements of distances traveled.

It must be remembered that Ptolemy's astronomical work was called the ALMAGEST, Arabic for the "greatest work," because it was so accurate. Vespucci had a set of astronomical tables based on the ALMAGEST that predicted there would be a conjunction of the moon with Mars on August 23, 1499, at 11:30 P.M. His set of tables was for Ferrara, Italy. From his position along the Asian coast he believed he was exploring, Vespucci observed the rising of Mars first, too far away from the moon to be called a conjuncture (FIGURE 14.1). The moon rose about ninety minutes after sunset. He also observed a difference of four hours between the time of the expected event in Ferrara and the local time clock on the new coast. Such a time difference from local time Vespucci calculated would give a westward position of sixty degrees of longitude from Ferrara. With the use of clocks and astronomical observations, Amerigo Vespucci derived a new and extremely accurate method of measuring eastward or westward progress on the globe. The accurate determination of latitude was developed in the ancient past by Ptolemy. Now longitude could be determined with equal accuracy. An independent verification of the results was also possible using triangulation developed from a base line formed from Ferrara to the Moon to Mars and the measurable separation between Mars and the moon which occurred because of the large distance between Vespucci's position along the unexplored coast and his homeland. The accuracy was limited to the accuracy

of clocks, but special times like sunrises and sunsets coordinated with planet positions permitted frequent correction of mechanical clocks at sea.

Amerigo Vespucci returned to this so-called Asian coast, the coast of Brazil, under the Portuguese flag with his own fleet of three caravels which left Lisbon May 13, 1501. His switching flags from Spanish to Portuguese was purely scientific. He desired to explore the Asian coast around 10 degrees South Latitude which by the Treaty of Tordesillas was placed in Portuguese administration. Vespucci explored and accurately mapped the Brazilian coast from near its easternmost extension to 50 degrees South Latitude near the modern port of San Julian and found no salt water passage to India. He returned to Lisbon in September of 1502. During this time he also developed an excellent map of the Southern Hemisphere stars noting their relative brightness. Turning to the difficult task of accurately drawing maps of the coastlines new to Europeans, Amerigo Vespucci concluded that the waterway at Catigara on Ptolemy's map did not exist on what he suddenly realized was a new fourth continent. With a great many mathematical calculations, Vespucci discovered at his map table in Seville, Spain that Columbus had not reached the outer islands of Cipangu, but instead had landed in a New World.

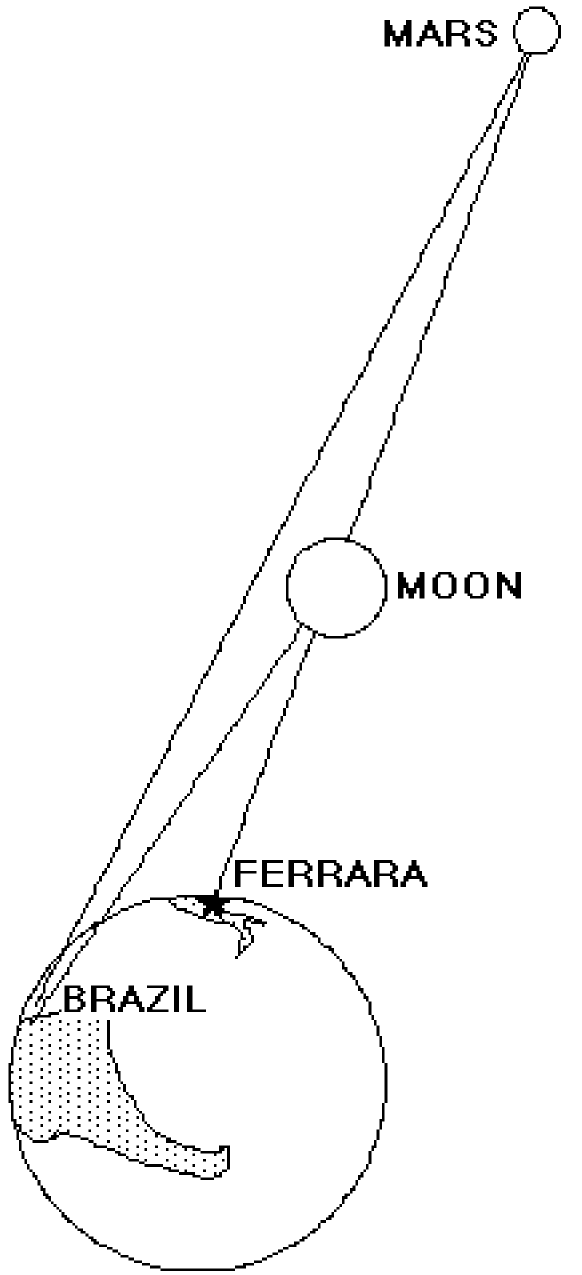

FIGURE 14.1 LINES OF SIGHT SHOWING A CONJUNCTION OF THE MOON WITH MARS AS SEEN FROM THE EAST COAST OF BRAZIL.

A clergyman in the small town of Saint-Die in northeastern France, Martin Waldseemuller, worked with a group of scholars and together they produced COSMOGRAPHIE INTRODUCTIO which included a major new map of the world that broke from the scientific tradition of Ptolemy's GEOGRAPHIE. It was not the first new map of the New World, but it did place a portrait of Ptolemy at the top of the map looking east and a portrait of Amerigo Vespucci looking west. On that map the name of the fourth continent was America. This map was printed by the newest invention of the day, the printing press, and within a year every scholarly school or business had a printed copy of the Waldseemuller

map.

Once a paradigm of thought is broken, a new one takes its place. The concept of a fourth continent meant the possibility of a new ocean. And of course if a new ocean were found, it would confirm the reality of the new continent. In September of 1513 Vasco Nunez de Balboa, leading a party of one hundred ninety Spaniards and a thousand natives, reached the summit of the Serraia del Darien and saw the Gulf of San Migual and the new great south sea beyond. From the Isthmus of Panama this new ocean was used immediately to pillage and rob the native cities of the west coast of America.

4. A NEW WORLD

Just six years later, on August 10, 1519, Ferdinand Magellan of Portugal sailed from S. Lucar de Barrameda, Spain, the port city of Seville, under the authority of Emperor Charles V with five ships and 243 men. His mission was once more to attempt to reach India by going west. Magellan had vowed to sail as far south as 75 degrees South Latitude if necessary to find a sea channel to the ocean seen by Balboa. Magellan arrived as far south as Vespucci, St. Julian, by August 24, 1520, and in a short while discovered the Cape of Eleven Thousand Virgins which was the entrance to the strait that bares his name, the Strait of Magellan, entering it on October 21, 1520. This passageway was 360 miles long, narrow and shallow in places, with snow capped mountains on both sides plummeting right to the water's edge. To the south Magellan saw many camp fires and named the immediate nearby land Tierra del Fuego. To Magellan it was the southern continent Ptolemy had placed on his ancient map and so the continent connected to Tierra del Fuego was named Magellan Land. On November 28, 1520, Magellan's fleet of four ships (one ship had deserted earlier) rounded Cabo Deseado (the desired cape) and entered the great south sea. Finding this new sea with gentle and steady winds, Magellan named it the Pacific Ocean. From this immense ocean he observed and mapped the position of the Magellanic Clouds, today known as galaxies of stars.

The enormity of the Pacific Ocean overwhelmed the courageous fleet. They came upon only two uninhabited islands, St. Paul's Island and Shark Island. With no chance for fresh food and water, they were forced to live off of putrid bilge water and ate ox-hides, sawdust, and rats. Scurvy took a terrible toll. Magellan himself was killed in the Philippines in a skirmish with the natives on April 27, 1521. The VITTORIA, the only surviving ship under the command of a Spaniard, Captain Sebastian del Cano, reached the Cape Verde Islands July 9, 1522. The surviving crew of 18 men, mostly Spaniards, were arrested and imprisoned by the Portuguese for a time before being allowed to complete the first recorded journey around the world. Scientifically, this globe-circling voyage, using mathematical methods of determining latitude and longitude, confirmed the size of the earth with a circumference of 25,000 miles, and by closing the circle permitted all new global maps to take on a greater degree of accuracy.

5. A RENEWED FAITH

On April 17, 1521, at the Diet of Worms, Martin Luther, a German theologian, stood before Emperor Charles V. Just ten days before, the Emperor's globe-circling explorer Ferdinand Magellan was killed trying to resupply his ship and find new people for the Christian empire of Charles V under the supreme authority of the Pope. Charles V saw Christian unity maintained by papal authority and saw his own imperial sword as part of that authority. The emperor's power was being used by the Pope to expand papal authority in both Asia and the New World. The emperor was also being used to quell Martin Luther.

Speaking for the court, for the emperor, and for the Pope, Dr. Eck challenged Luther. Martin Luther, standing on the only authority with certainty, insisted on SOLA SCRIPTURA.

Questions concerning the Bible could only be answered by the Bible. SOLA SCRIPTURA, a watchword of the Reformation, freed us all from human authority in matters of the Holy Scriptures. While the old authorities over human wisdom, laws of science, were being drowned at sea by one discovery after another, human self-ordained authority over Scripture was being condemned by the Word as that Word was being returned to all of God's people who could read, hear, and learn it. Though much raging by those in authority would follow, the Reformation had freed all thoughts and opened the door to a new age of free thinking as has never been known since. Concerning the history of science, the Reformation meant for the scientist that Aristotle did not have to be accepted as a scientific authority just because a few centuries earlier Christian scholars merged Greek pagan science with papal interpretations of the Bible.

Luther wrote as an explanation to the first article of the Apostle's Creed:

"I believe that God made me and every creature and that he gave me my body and soul, eyes, ears and all my members, my mind and all my abilities. And I believe that God still preserves me by richly and daily providing clothing and shoes, food and drink, house and home, wife and children, land, cattle and all I own, and all that I need to keep my body and life, and by defending me against all danger and guarding and protecting me from all evil. All this God does only because he is my good and merciful Father in heaven, and not because I have earned or deserved it. For all this I ought to thank and praise, to serve and obey him. This is most certainly true." (Martin Luther, THE SMALL CATECHISM)

All things in nature are of God. Even our mind and its ability to reason is a gift from God. While the Christians of a few centuries earlier could accept inductive reasoning and invent laboratory science because they knew God created all things with order, Luther now showed that authority rests in God. Luther showed that the Creator and His work of creation are known with certainty in the Scriptures alone. The Christian is free from the added authority that human beings might demand. The free person has been given a mind to reason on his or her own without parroting some other human authority such as Aristotle.

Luther was also fully aware that human reason rested on a person, who by nature was a sinner, who used his or her reason in a sinful manner, not always looking to his or her Lord for authority and certainty. For an explanation of the third petition of "The Lord's Prayer" Luther had children memorize:

"God's will is done when he breaks and defeats every evil plan and purpose of the devil, the world and our sinful flesh, which try to prevent us from keeping God's name holy and letting his kingdom come. And God's will is done when he strengthens and keeps us firm in his Word and in the faith as long as we live. This is his good and gracious will." (Martin Luther, THE SMALL CATECHISM)

Luther taught everyone to go to the Triune God in prayer and with believing faith. Their Lord was the authority--not popes, not philosophers, not scientists, not even one's own reason.

To Luther, Aristotle was a trusted authority for the physical explanation of the rainbow. Luther always respected reason as a great gift from his Lord, but when that reason challenged or added to Scripture, Luther was quick to return to a childlike faith by referring

to the Scriptures. He spoke of the rainbow in his lectures on Genesis:

"The rainbow makes its appearance even now, to be a sure sign that a universal flood will not occur in the future. Hence this promise demands also from us that we believe that God has compassion on the human race and will not rage against us in the future by means of a universal flood."

"There is further discussion at this point whether there are natural causes in the rainbow that convey this meaning. And the discussion of the philosopher is familiar, especially that of Aristotle in his METEOROLOGICA, about the color of the rainbow, about the nature of the cloud in which it originates, and about its curvature. Rather appropriately, they include a comparison with mirrors, in which an image is reflected in the same way the rays of the sun are reflected, and produce a rainbow when they fall upon a moist and concave cloud. In such matters reason sees what is most likely to be the case, even though it is incapable of determining the truth in every instance; for this is the prerogative, not of the creature but of the Creator. Yet I for my part have never given less credence to any book than to the METEOROLOGICA, because it is based on the principle that all things have their origin in natural causes."

"I do not despise human thoughts and surmises about these things; but because the proofs are not substantial, I do not place too much confidence in them. Furthermore, the surmises of Aristotle about a moist and concave cloud are not reliable, because such clouds can exist even when no rainbow develops. Indeed, from either a denser or a more tenuous medium there can develop a rainbow that either is larger or forms a greater arc. Here in Wittenberg I personally observed a rainbow round like a circle and closed on all sides, not cut off on the surface of the earth, the way it ordinarily appears. Why, then, do rainbows develop sometimes in one way, sometimes in another? A philosopher, I am sure, will figure out something, for he will regard it as a disgrace not to be able to give reasons for everything. But he certainly will never persuade me to believe that he is speaking the truth."

"This sign should remind us to give thanks to God. For as often as the rainbow appears, it preaches to the entire world with a loud voice about the wrath which once moved God to destroy the whole world. It also gives comfort, that we may have the conviction that God is kindly inclined toward us again and will never again make use of so horrible a punishment. Thus it teaches the fear of God and faith at the same time, the great virtues. Philosophy has no knowledge of these and carries on a discussion solely about the material and formal cause; it does not know the final cause of the beautiful creature. But theology points it out." (LUTHER'S WORKS, Vol. 2, pages 146-148, reprinted by permission, Concordia Publishing House)

Luther points to the strengths of human reason. It was a good gift that God gave the explorers, to use their reason and ability to challenge the old views of nature and discover new. But by appeals to efficient and final causes, identified by Aristotle, Martin Luther points out there is much more to the natural world than just material and form. God has His plan in the natural world, and human explanations of that natural world cannot approach truth without knowledge of God's works even if it may mean some things are beyond human understanding.

In a complete study of Martin Luther's use of reason titled THE FOOLISHNESS OF GOD, Siegbert Becker identified four uses. Reason was a source for learning. It was this use of reason whereby most things of science are learned. A person was negligent and, in fact, guilty of tempting God if he did not use his reason. Reason in this manner was even capable of discovering that God existed although in this role of reason, the knowledge of

God was totally inadequate, remaining entirely legalistic, and never finding a Savior. Likewise in science, reason remained always limited, never fully grasping efficient and final causes for the things in nature, never fully by reason knowing the Creator and all that He does and accomplishes with nature. Reason to Martin Luther was a powerful instrument with which to understand and come to the knowledge of Christ and His wonderful work by studying the Holy Scriptures. In that role reason serves faith given by the Holy Spirit in a most marvelous way. Reason was used as a defender of the faith. Martin Luther concluded reason and syllogistic demonstration or logic had not been tarnished by sin; only the sinner with his wicked desires used reason and logic wrongly. Thus reason could be properly used to correct error or at least show erroneous steps to erring logic. But this role for reason had only a limited purpose. Such reason could never give the certainty faith could. The fourth role of reason was that of judge. This use Martin Luther had utter contempt for. Reason could never pass judgment on the Holy Scriptures or go against its very Creator in doing so. The Scriptures, the truth which they profess, can only be apprehended by faith alone.

Martin Luther, through the Reformation, freed the scientist from the bondage of papal authority, from the bondage of Aristotelian authority, and even from the bondage of one's own reason. First in the northern Protestant countries and then everywhere, men of science responded with one new thrilling discovery after another in the century following the Reformation. Scholars who made innovations in experimental science at Oxford in the thirteenth century, stopped by a church requirement for allegiance to Aristotle, were again free. The findings at sea overthrew both Ptolemaic geography and Aristotelian oceanography, but the sailors may never have gone out on to the uncharted sea without the Christian hope of open seas given by their wrongly constructed maps with six parts of water to one part of land.

The Christian's will and his reason remained bound to the Holy Word of God. It would not last. After several centuries free of papal authority and free from ancient authorities, many scientists would try to become free of God's authority and would worship the beast, but for a time harmony between science and the nature God created appeared strong and much was accomplished.

6. A NEW SCIENCE

On December 13, 1577, Francis Drake set sail to circumnavigate the world for the crown of England. He departed with five ships and one hundred sixty-six men and returned September 26, 1580, with one ship and fifty-seven men. Their notable discovery was the passageway on the south side of Tierra del Fuego. Drake had entered the Pacific Ocean from the Strait of Magellan. The second day on the Pacific Ocean, drawn by winds to the south, Drake perceived they were overcome by a major storm. It may simply have been normal winds and waves of the screaming fifties. As the ships came into the mixture of the South Pacific and Antarctic convergence zone which in turmoil gushed into the Atlantic Ocean, high winds, heavy seas, and strong current rarely recorded scattered Drake's fleet back eastward and below 56 degrees South Latitude into ocean waters more than five hundred fathoms deep. In spite of these terrific conditions, Drake made a positive statement claiming that he could navigate in both directions through the new passage, the Drake Passage. There was no land that could be sighted to the south. Magellan Land did not exist. An account of that discovery was recorded by Francis Fletcher, a preacher with Francis Drake's expedition.

"For September 7 the second day after our entrance into the South sea (called by some MARE PACIFICUM, but proving to us rather to be MARE FURIOSUM) God by a contrary

wind and intollerable tempest, seemed to set himselfe against us: forcing us not onely to alter our course and determination, but with great trouble, long time, many dangers, hard escapes, and finall separating of our fleet, to yeeld our selves unto his will. Yea such was the extremitie of the tempest, that it appeared to us as if he had pronounced a sentence, not to stay his hand, nor to withdraw his judgement till he had buried our bodies and ships also, in the bottomlesse depth of the raging sea. . . ."

"From the seventh of September (in which the storme began) till the seventh of October we could not by any means recover any land (having in the meane time been driven so farre South, as to the 57 deg. and somewhat better) . . ."

"But escaping from these straites and miseries, as it were through the needles ey (that God might have the greater glory in our delivery) by the great and effectuall care and travell of our Generall, the Lords instrument therein; we could now no longer forbeare, but must needes finde some place of refuge, aswell to provide water, wood, and other necessaries, as to comfort our men, thus worne and tired out, by so many and so long intellerable toyles: the like whereof, its to be supposed, no traveller hath felt, neither hath there ever beene, such a tempest (that any records make mention of) so violent, and of such continuance, since NOAHS flood, for as hath beene sayd it lasted from September 7 to October 28, full 52 dayes. . . ."

"The uttermost cape or hedland of all these Ilands, stands neere in 56 deg. without which there is no maine, nor Iland to be seene to the Southwards: but that the Atlanticke Ocean, and the South sea, meete in a most large and free scope." (Francis Fletcher, THE WORLD ENCOMPASSED)

The entire world was new. Geography according to Ptolemy had nothing to offer the new age of science. The discoverers found new oceans, great ocean currents, great wind systems in the wide open sea far from land, new continents, new stars, and new races. The ocean currents and wind systems would turn the wide ocean barriers into navigable highways of trade and communication. Though the earth always was a sphere, it now was a very different sphere, a very knowable sphere. There was far more to nature than what was written about it in a book of authority in a library. Science did not have even the beginning of the answers for all the new discoveries in God's creation, but the new maps and the new world views gave new encouragement to the pursuit of knowledge.

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SEPARATE FROM HIS WORD

FIGURE 15.1 CRASHING THROUGH ARISTOTLE'S SPHERE OF STARS.

THE SHATTERED CRYSTALLINE SPHERES:
Copernicus to Newton, Chapter 15

A sixteenth century motif (FIGURE 15.1) shows a man crawling on the ground with his head and shoulders crashing through the horizon formed by the sphere of stars which shape a dome over the entire landscape. On the outside of the shattered sphere lie all sorts of other rings and wheels with planets and a sun among the wheels. Many interpret this as a peering out into Ptolemy's universe of epicycles, and with the presence of the sun among the wheels, that very well could be. The real statement this motif was making in the sixteenth century was the shattering of Aristotelian science. Some might have seen Ptolemy's work as part of the Aristotelian overthrow since the Latin translation of Ptolemy's astronomy did not emerge until 1538. Copernicus' REVOLUTIONS OF HEAVENLY SPHERES, which also contained many circles and epicycles, was published in 1543. Although the earth as a moving planet created a larger intellectual revolution, both the renewed Ptolemaic vision and the Copernican vision looked through the rigid crystal spheres of Aristotle and shattered old views of the heavens. Open floating circles in space gave a freer, wider, more distant view of the universe, and the telescope would soon confirm that view by looking beyond the crystalline spheres. Authority of every kind, except the authority of the Bible, was being questioned. At sea a new world map was being made, ancient views of nature were challenged, and the papal authority over all aspects of human life was rejected. The freedoms that emerged created a golden age of discovery for science.

While making these new revolutions, men of science responded with praise to their Lord and Savior, and they always recognized the Creator and His Word as the final authority. Copernicus rejoiced in the astronomical works of his Lord's hands. In the revolution in the biological sciences led by William Harvey, he claimed his motivation for science was the

understanding of order given by the Creator. A clear distinction was made by Blaise Pascal between the ability to be critical of the ancient scientific authorities and the authority of the Holy Scripture. Galileo, who had much trouble from the clergymen of his church, made it quite clear he never challenged the authority or role of God in nature. Johannes Kepler humbly confessed limits of human knowledge and acknowledged mistakes in past Christian history with respect to science in his preface to the reader of EPITOME OF COPERNICAN ASTRONOMY, Book IV, 1621, and broke into a song of praise to the Creator in the conclusion of THE HARMONIES OF THE WORLD, 1619.

The freedom discovered at sea and proclaimed in the Reformation said God's creation was larger than could be imagined and the individual was bound to his Creator directly, not through human authority, but only through the inspired Scriptures. That freedom did not come without great cost of blood, toil, and tears. Copernicus, who on his deathbed received the first copy of his life's work proposing the new heliocentric system of the universe, was graciously spared the turmoil that would result in both Protestant and Catholic camps of Europe. Tycho Brahe, who compiled the most accurate astronomical data in written history up to his time, was threatened with charges of heresy and returned to a Ptolemaic geocentric view. Giordano Bruno accepted Copernican ideas, even suggested the sun might be moving, and for this was burned at the stake for heresy. Galileo Galilei taught and published written works on heliocentric astronomy for which he was tried for heresy by the Inquisition, was found guilty, was shown the instruments of torture, and recanted. Johannes Kepler found a freer spirit of acceptance for his heliocentric and elliptical orbits in Protestant countries, yet had to spend much of his life fleeing purges against Protestants.

In such a frustrating climate intellectual innovations had difficulty surviving. The Thirty Years War of Europe, fought primarily on German soil but embroiling Sweden, France, and Spain, curtailed scientific discovery in spite of the birth of religious and intellectual freedom.

1. NIKOLAUS COPERNICUS, 1473-1543

There was really no overwhelming need to develop a new explanation for the motion of stars and wanderers in the heavens. Plato's assignment to look for the explanation of planetary motion in terms of circles and spheres was well accepted. Aristotle's concentric system of spheres adequately explained the structure of the universe. There was renewed interest in Ptolemy's ALMAGEST since its Latin translation in 1458. The ALMAGEST gave exact positions of the stars and planets, and these permitted global navigation even into the uncharted southern seas using uncharted southern stars. An Aristotelian or Ptolemaic view of the planets and stars explained the motions that were visible as real motions. The stars visibly moved as a great dome or sphere, so a scientific explanation that the stars were all in one large crystalline sphere was confirmed by observation. The planets were seen to make retrograde loops under the sphere of stars; thus, a multiple combination of spheres interlocked together or multiple epicycles preserved the perfection demanded by Plato. The Christians, who knew their God created all things with perfection, embraced Plato's demands for circular perfection. Such circles or spheres showed how the real visible paths of the planets traced out real retrograde loops.

Quite in the spirit of intellectual freedom, Nikolaus Copernicus tried to develop a new explanation making note that the different explanations of planetary motion by Philolaus (480-400 B.C.) or Aristarchus (310-230 B.C.), although not accepted in the Middle Ages, had never been refuted either. The reader will recall that Philolaus suggested the earth

revolved around an invisible fire, and Aristarchus had the earth revolve around the sun. Copernicus displayed his innovative genius by suggesting that the earth had a double motion. Instead of the entire sphere of stars turning on an axis through Polaris, he suggested the earth spun on its axis through the two poles. The stars only looked like they were moving around the earth once in four minutes short of a full day. The second motion of the earth was forward motion around a circle around the sun (FIGURE 15.2). It was this second motion in a circular path around the sun that produced the four minute discrepancy between the time it took to see a star return to its original place in the sky and the sun to do the same. With the earth traveling forward around the sun at the same time as it was spinning, it must turn back slightly farther, by four minutes of time, to see the sun (FIGURE 15.3). Thus, by marking time as solar days of twenty-four hours, star positions at the same local time each night would be slightly farther westward.

Copernicus had established his own astronomical observatory at Frauenberg, Poland, in 1506 and developed a strong reputation as a mathematician and astronomer. His first publication on his heliocentric theory came in 1530 in a brief outline form called the COMMENTARIOLUS. Joachim Rheticus, a protege of Philip Melanchton and a professor of mathematics, visited Copernicus in 1539 and in the free spirit of the Reformation became very receptive to these new ideas. Rheticus wrote his own summary of the heliocentric theory with Copernicus' approval in 1540 and became very instrumental in having Copernicus' masterful work ON THE REVOLUTIONS OF THE HEAVENLY SPHERES published on the new printing presses at Nuremberg in 1543. Andrew Osiander, another Lutheran theologian, wrote the introduction for Copernicus.

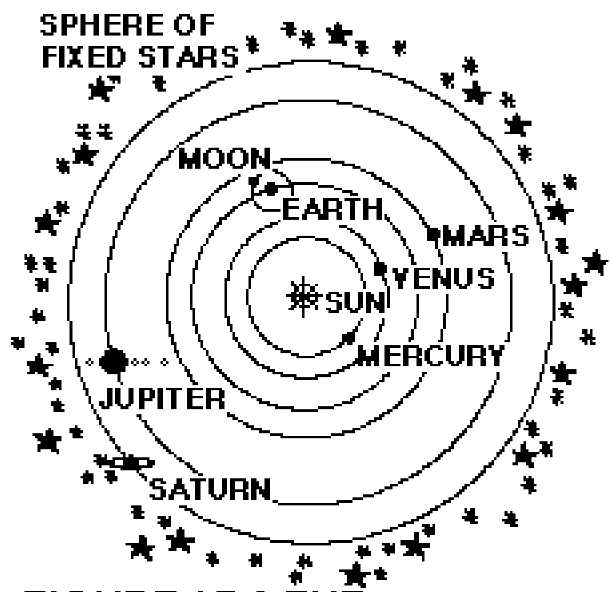

FIGURE 15.2 THE COPERNICAN SOLAR SYSTEM.

This revolution in scientific thought occurred not by observational evidence, but by the new world view changing all the definitions that the observations might be viewed differently. The earth, a singular place or the center of universal gravity, suddenly became a wanderer, a planet. Former planets, the sun and moon, became special objects in separate classes. The sun eventually became the solar system's star, and the moon became the earth's special satellite. Motions thought to be real became apparent motions witnessed from a moving planet. The previously undetectable motion of the earth became real by interpreting the apparent motions. Copernicus' system actually was not that well supported by evidence and could not solve many problems a Ptolemaic system could. Copernicus retained the sphere of stars keeping the size and shape of the universe finite and spherical. He insisted all celestial bodies had to display God's perfect order and thereby always trace out circular paths at constant speed. Where observational evidence strongly opposed such an interpretation, Copernicus resorted to epicycles.

Mars and Venus, for example, display large fluctuations in relative speed against the sphere of stars and also show a great change of apparent brightness. Eccentric adjustments, placing some planetary orbits slightly off center, also were used by Copernicus to maintain some observational integrity.

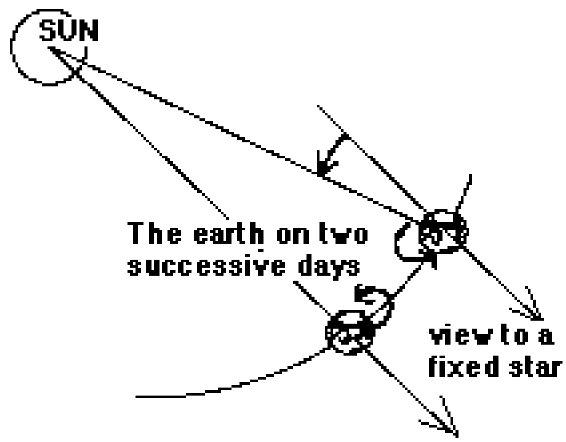

FIGURE 15.3 THE EARTH'S FULL TURN WITH RESPECT TO THE SUN TAKES FOUR MINUTES LONGER THAN A FULL TURN WITH RESPECT TO A DISTANT STAR.

Osiander was correct when he encouraged others to exercise caution before accepting the new Copernican idea. At the University of Wittenberg both Martin Luther and Philip Melanchton were critical of the heliocentric theory on the basis of Joshua 10 where the Scriptures clearly state that the sun stood still. It would take several centuries before most theologians would view the sun standing still over Gibeon and the moon also standing still over the valley of Aijalon as the true apparent motions witnessed from the battlefield in the same way that Copernicus and his astronomical followers viewed the sky. In fairness to Copernicus' critics, heliocentric theory in 1543 was not accepted overnight. Much remained unexplained. Some major problems were better explained by Aristotle or Ptolemy. Heliocentric theory, like all scientific explanations whether law or theory, was a work of art. With brush strokes of numerical calculations, Copernicus' system tried to match the motions in nature, but they remained separate from nature. Osiander was quite correct in 1543 that no one could provide true causes for the motions of the planets.

The chief objection came from the same source it had come from against the Pythagoreans. Aristotle's works, taught in every university, still asked for a witness of oscillating motions among the stars moving in opposite ways than the supposed earth motion (FIGURE 8.2). In the days of Philolaus and Aristarchus, such motion, today called heliocentric parallax, could not be seen. In 1543 it could not be seen either. It must be most significant to the student of science that condemning evidence does not overthrow theory or law. Such fundamental motions, apparent motions viewed from a moving platform, had to be observed if indeed the platform was moving. Aristotle knew that if the earth moved, then heliocentric parallax had to be observed. Men in the sixteenth century knew that also, but the needed phenomenon was not seen. It was theory-saving rationale that shattered right through the rigid crystalline sphere of stars. Rather than reject Copernicus, university scholars in the Reformation spirit imagined the stars so far away that motions of heliocentric parallax could not be seen. Instantly the concept of the universe changed from a finite universe ending in the sphere of stars to an infinite universe with the stars so far away that they seemed fixed.

Retrograde loops of the planets, the very motion that attracted the ancients to the planets as special objects in the sky, now became a major stumbling block to Copernican motion. It is for these retrograde loops that Copernicus kept epicycles, but the need for change from Ptolemaic epicycles to Copernican epicycles seemed nil. A solution eventually offered showed a planet observed from the earth with both moving. The more distant

planet moved slower and thus was overtaken from behind by the earth and passed up. With this passing, the more distant planet appeared for a time to move backwards compared to a background of more distant stars (FIGURE 15.4). Again a major observable motion in the sky was no longer viewed as a real motion, but only as an apparent motion as a result of the surmised motion of the earth which was not observable.

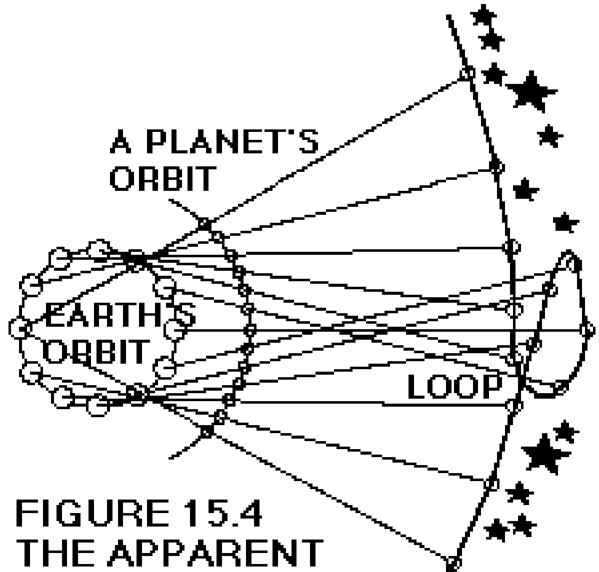

FIGURE 15.4
THE APPARENT RETROGRADE MOTION OF A PLANET VIEWED FROM A MOVING EARTH AGAINST THE FIXED STARS.

2. WILLIAM GILBERT--MAGNETISM

Quite apart from astronomy, Robert Norman, a navigator with more than twenty years of experience at sea for England, developed a new intellectual tool, the magnetic "field," to explain magnetic forces of attraction at a distance. To show that a magnet was surrounded by a field and not just a force, he developed a small magnet imbedded in a cork that would at first float on a liquid in a large deep container. The magnetic needle would point to the magnetic north and south but would not migrate to one side of the container. This showed the magnetic needle was lined up with the magnetic field but was not pulled forward by the earth's magnetic force. He then shaved the cork until he achieved the exact same density for the combined needle and cork as the density of the liquid surrounding them. A magnetic needle in such a cork could be placed submerged but also suspended in the liquid and would show the three dimensional alignment along magnetic field lines without any migration of forward movement of the magnetized needle. Norman also discovered magnetic dip was related to latitude at sea and published his results in a book titled THE NEWE ATTRACTIVE (published by Ballard in London, 1581). These findings then became the forerunner to the great work of an English medical doctor, William Gilbert, in his work titled ON THE LOADSTONE AND MAGNETIC BODIES AND ON THE GREAT MAGNET THE EARTH published in 1600.

William Gilbert concluded the earth itself was one great magnet, and all compasses anywhere in the world merely lined up in the earth's magnetic field. Magnetic dip could be related to latitude, and magnetic deviation from astronomical north could give a better approximation of longitude than dead reckoning until clocks at sea could be improved. Most important for astronomy, Gilbert was one of the first major internationally recognized scientists to be supportive of Copernicus' heliocentric view of planetary motion. Gilbert reasoned like an Aristotelian. The earth was a giant magnet. All other magnets were made of material of the earth. Just as stones made of the earth gravitated to the earth by falling down, so all magnets fell down when let go. A magnet had within it a spin which it displayed as it was held over the earth. This spin of the magnet originated in the earth which also must be continually spinning. For the first time, science had provided at least a material and formal cause for the earth's spin. Spinning was natural to all earth materials and magnets proved it.

The Copernican view of the solar system began to take hold of the scientists of the world, but with success came opposition. It is interesting to note that the great geographical discoveries were made before the new astronomy and the new understanding of magnetism. Sailors believed in Ptolemy's geography and his astronomy led the way across the sea. Compasses were often mistrusted or considered a tool of the occult. Most efforts in scholarly centers were directed toward simple and common materials such as garlic juice that might inhibit the occult powers of magnetism until William Gilbert could give his Aristotelian explanation of a global magnet spinning. Actually, the magnetic dip and deviation from true north made global navigation simpler and quickly replaced the more complicated navigation by the Copernican motions of the heavens. Many sailors continued to navigate using the pragmatic Ptolemaic measurements which still gave an excellent view of the motions of the heavenly bodies as viewed from the earth.

3. TYCHO BRAHE

The observations taken by Tycho Brahe (1546-1601) are of legendary quality in most modern astronomy books today. A problem exists, however, that most textbooks of science, in an effort to get across the world view of today, present only that portion of history which leads to the modern "correct" answer. Indeed, the astronomical observations made by Tycho Brahe were the very best up to his time. They did not confirm Copernicus' theory.

While Tycho Brahe was studying law at the University of Copenhagen, a total eclipse of the sun was predicted for August 21, 1560. That prediction turned out to be exactly correct. He was so impressed with astronomy that he dropped his law studies and concentrated on the ALMAGEST by Ptolemy. In August of 1563, an impressive conjuncture of Jupiter and Saturn occurred, but the astronomical tables generated from the ALMAGEST were greatly in error. Copernican tables likewise missed the time of conjuncture by several days. For nearly all of the next decade, Brahe traveled and studied astronomy and mathematics at several universities including the University of Wittenberg. On November 11, 1572, he was the first to record and map a new star in the constellation Cassiopeia which was brighter than Venus. Following and mapping the star, today identified as a supernova, Tycho Brahe mathematically determined it was farther away from the earth than the moon and published his results in DE NOVA STELLA in 1573.

This discovery proved to be an outstanding anomaly for Aristotelian thought, especially after a changeless sphere of stars had been made a religious doctrine by Thomas Aquinas. The celestial world, the universe above the moon, was God's realm which was as changeless as God Himself. Accordingly, there could be no new star. Telescopes, not yet invented, could not show that this was just an explosion of an already created star, but that also would not have been accepted. Tycho Brahe received instant celebrity status and was granted the Island Hven and a sizeable stipend of support from King Frederick II of Denmark. During the next twenty years at this richly endowed observatory at Hven, the most accurate observations of the heavens up to that time were made. Tycho Brahe mapped 719 stars and found several new stars. A comet was followed, mapped, and by mathematical means determined to be beyond the moon; therefore it could not be earth exhalations from a drought-stricken land as claimed by Aristotle. The path of the comet also was much different than a circle. Tycho Brahe's calculations of this comet's motion were the first challenge to the time-honored solution of the perfect motions of the celestial world according to Plato. Tycho Brahe discovered perturbations of the moon from which he suggested that maybe the orbits of the planets were not circular.

Such observations indeed approached legendary proportions, but they did not confirm Copernican theory of heliocentricity. Brahe paid special attention to the data for Mercury and Venus, which were planets along with the moon in a separate category from the other planets in Ptolemy's system. Mercury and Venus, when evening stars, never were found near the zenith angles near the middle of the sky. Both of these planets set shortly after the sun set. He also noticed with the twenty years of excellent data that these same two planets, when they were morning stars, always rose shortly before sunrise and again never were seen in the central southern portion of the sky (FIGURE 15.5). Tycho Brahe concluded Mercury and Venus orbited the sun in epicycles while the sun orbited the earth (FIGURE 15.6). With these alterations Tycho Brahe restored Ptolemaic astronomy with the most accurate astronomical measurements known to mankind up to A.D. 1600.

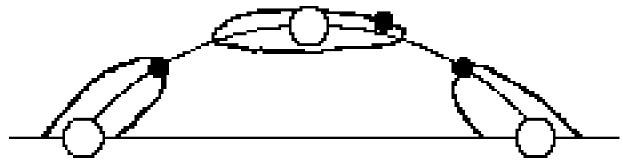

FIGURE 15.5 THE VISIBLE PATH LIMIT OF VENUS AT SUNRISE AND SUNSET LED BRAHE TO THE VIEW OF VENUS AND MERCURY AS ORBITERS OF THE SUN.

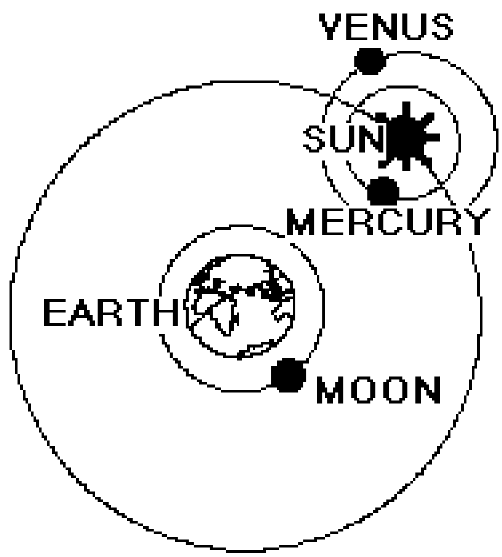

FIGURE 15.6 BRAHE'S EARTH CENTERED UNIVERSE.

When Tycho Brahe's patron king died, so did his funds. For two years he searched for a new patron visiting Hamburg, Dresden, Wittenberg, and finally was granted Wandsbeck Castle and the position of imperial mathematicus by Emperor Rudolph II in Prague. This move brought him within a short distance of a young Lutheran astronomer, Johannes Kepler, on whom he had much influence.

4. GALILEO'S ASTRONOMICAL DISCOVERIES

Galileo Galilei, a devout and loyal Roman Catholic, who held the chair of mathematics at the University of Padua and was well known throughout Europe for his work with moving objects, provided a new paradigm for such motion rather different than that of Aristotle. He gave impressive physical demonstrations refuting Aristotelian explanations of motion and frequently attracted audiences of more than a thousand students. In 1609, using several magnifying glasses and a tube, he put together a telescope and trained it on the sky for the first time, and at once discovered the Milky Way was not a band of fire continually burning at some level below the moon. Instead the Milky Way consisted of a

countless number of stars made clear by the telescope. The certain explanations of Aristotle faced rejection as the universe was seen filled with thousands more stars then ever could be imagined. With this telescope Galileo failed to see heliocentric parallax (FIGURE 8.2) so that the Aristotelian demand for final acceptance of a Copernican view of the heavens could not be met. Yet the enlarged universe confirmed for Galileo that Copernicus' solar system was correct. The telescope also permitted Galileo to see the rings of Saturn, four moons of Jupiter, eroded mountains on the moon, and moon-like phases showing crescents for both Mercury and Venus. Galileo even discovered and mapped the rotation of the sun by following sun spots with his telescope. These observations of the sun may explain why he went blind later in his life.

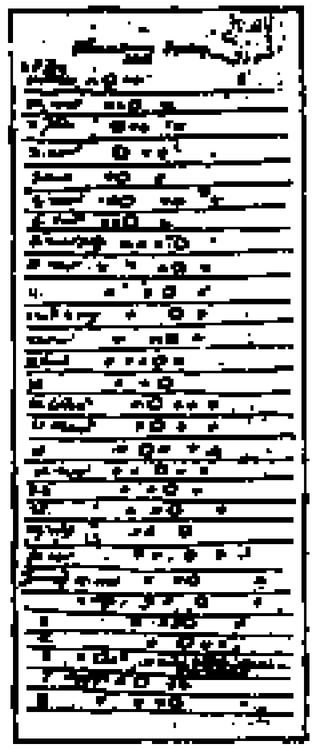

FIGURE 15.7 GALILEO'S NOTEBOOK SKETCHES OF THE CHANGING MOTIONS OF THE MOONS OF JUPITER.

At once Galileo was in trouble with his church for heresy. The celestial domain was perfect and as changeless as God according to the church. Blemishes such as erosion of mountains on the moon or spots on the sun were heretical ideas. The moons of Jupiter showed a micro solar system (FIGURE 15.7, Reprinted from NASA), a small model of a Copernican universe. Crescent views of Venus and Mercury waxing and waning (FIGURE 15.8) confirmed their orbits around the sun. With the telescope, variable brightness of most of the planets also could be explained by Copernican theory. By 1616 Galileo was summoned to trial by the Inquisition and ordered to cease publishing and teaching the Copernican view that the earth was not the center of the universe and that the earth moved. In the turbulent wake of the Reformation another challenge to the authority of the Pope and his church could not be tolerated.

Not one to give in to authority without reason, Galileo persisted with his astronomical studies, although he wrote in a non-scientific parable form. He wrote an imaginative dialogue between three people in which hypothetical questions from both the Ptolemaic system and the Copernican system could be questioned freely and debated openly. Little scientific data and no elaborate data tables were used. Persuasion, sometimes condemnation, and sometimes ridicule were used to finally express a favorable and convincing view of Copernicus' theory. The book DIALOGUE OF THE TWO PRINCIPLE SYSTEMS OF THE WORLD written in 1632 had global acceptance and served as a popularizing version of the very mathematical and complex work of Copernicus. Galileo was condemned of heresy and shown the instrument of torture which was a stretching machine that pulled legs and arms out of their sockets, leaving the victims paraplegic at best or to die a slow and painful death in a helpless heap. Trained as a medical doctor and

understanding the brutal disruption to one's anatomy such a device could achieve, Galileo recanted, was confined to house arrest, and was not permitted to publish for the rest of his life.

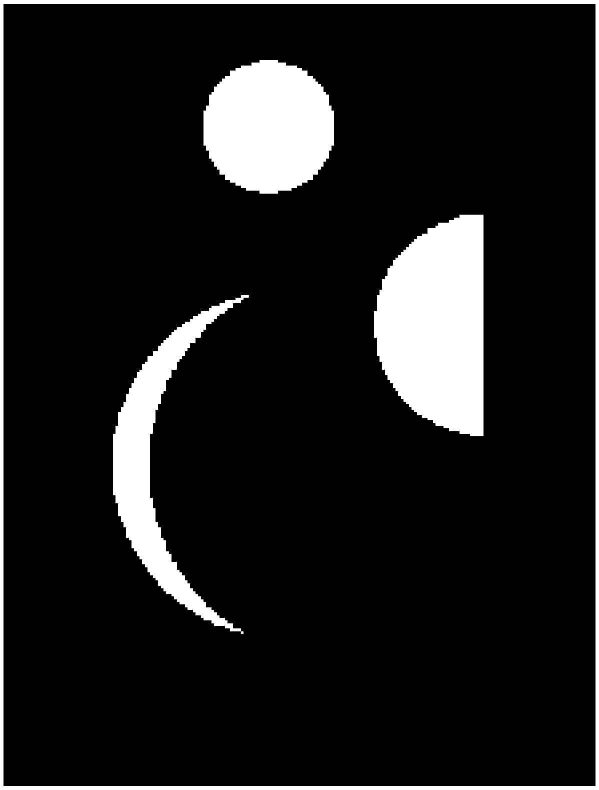

FIGURE 15.8 MOON-LIKE PHASES OF VENUS SEEN THROUGH A TELESCOPE.

5. NEW ORBITS FOR THE PLANETS, JOHANNES KEPLER

Considerable communication occurred between Galileo, Brahe, and Kepler. While Galileo incurred the wrath of his church, Kepler found some intellectual freedom in the Lutheran provinces and finally ended up in Prague near Brahe. Johannes Kepler (1571-1630) went on to develop the three laws of planetary motion that carry his name to our time. He was the mathematician who could take these views of Copernicus and use them to add meaning to the strange non-Aristotelian phenomena found by Galileo's telescope. His work was primarily achieved at his desk since he was nearly blind and had crippled hands after surviving smallpox as a very young child. Coming from a poor home, he was educated in the publicly supported Lutheran school and even achieved a college education at the Lutheran University of Tuebingen. At the university the new idea from Copernicus was openly taught so Kepler from the beginning of his education learned to accept this new astronomy.

Kepler pursued several strange ideas. He set out to explain causes for the limited number of planets and their relative distances apart and turned to the Pythagorean solids--the tetrahedron of four equilateral triangles, the cube of six squares, the octahedron of

eight equilateral triangles, the dodecahedron of twelve pentagons, and the icosahedron of twenty equilateral triangles. These five solids could be arranged in such a way to stand between Aristotelian planetary spheres. This would give six spheres to fit the six Copernican planets of Saturn, Jupiter, Mars, earth, Venus, and Mercury. He reasoned there could be no more than six planets allowing some planets to have moons. The sun, not a planet, took the central position. In detail, first came the sphere of Saturn on which the planet of Saturn was attached. Inside that sphere, touching the sphere only at the points, was a cube. Inside the cube, touching only the midpoint of each square face, was the sphere of Jupiter upon which was connected the planet of Jupiter. The complete sequence followed: tetrahedron, sphere of Mars; dodecahedron, sphere of earth; icosahedron, sphere of Venus; octahedron, sphere of Mercury (FIGURE 15.9). In time Kepler's own observations demonstrated to him that such a system failed.

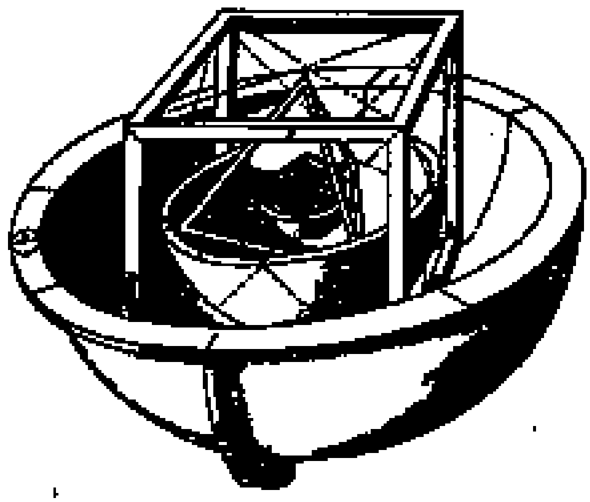

FIGURE 15.9 KEPLER'S SOLAR SYSTEM WITH DISTANCES DETERMINED ACCORDING TO THE PROPORTIONATE SPACING OF THE PYTHAGOREAN SOLIDS.

Kepler built another system, also on a Pythagorean idea. Believing that the universe had to show a perfect plan of order to declare God's glory, Kepler sought musical harmonies to explain each planet, its position from the sun, and its variable speeds. In THE HARMONIES OF THE WORLD, 1619, Kepler described each planet with a continuous series of tones rising and falling in pitch. The highest average pitch was for Mercury, the planet closest to the sun. The lowest average pitch was for Saturn, the farthest planet from the sun. The variance in pitch for a particular planet was related to the varying distances that planets appeared from the sun while in a given orbit. Such music could not be played in Kepler's time. These sounds could be heard only after the invention of the electronic synthesizer and the electronic computer through which planetary data could be converted into Kepler's harmonies in our time (John Rodgers and Wille Ruff of Yale University, 1979).

Mixed with these seemingly strange astronomical studies of Kepler from 1609 to 1621 are the three laws of planetary motion generally accepted today. These laws were never listed together, nor isolated as more special than the Pythagorean solids or the musical harmonies. This is how real scientific explanations come to us. Today we are simply too close to the modern works to see the jewels among countless other correlations of little meaning. And of course what was important in its day of discovery is different from what becomes important using blinders or the insight of a different age. The musical harmonies as God's heavenly musical order was especially important to Kepler, but appears as nonsense today.

The musical harmonies represent a complete and an exact mathematical model of the motion of all of the planets. That achievement was built on knowledge from Copernicus and Galileo with the detailed observations collected over a lifetime of work by Tycho Brahe. It is nearly impossible to grasp the difficulty of developing such a unified system for the motions of all the planets, especially if we consider the reality that we know neither the motion of any object visible in the heavens and also simultaneously do not know the motion of the earth. Kepler began by knowing he could never see where a planet was but only in what direction it could be seen from the earth. To start, some knowledge must be assumed about the motion of the earth; and with that assumption, before we ever start, we remove the certainty of discovering the motion of the earth.

Kepler made his assumption that of the Copernican view, that the earth moves around the sun. Working from the known earth-sun line in three dimensional space and claiming the sun motionless as a starting assumption, it could be observed that over many years of time the earth-sun line remains in the same plane. That permitted the angular changes of the earth-sun line to be mapped as a plane on a simple sheet of paper without projection problems. The angular velocity (the angular measurements change with respect to a unit of time) of the earth-sun line around the fixed sun with respect to the fixed stars on the outside edge of the map showed variable motion but with an annual repetition. For example, the earth-sun line swept out a wide angle in January and a narrow angle in July, but always the same angle in the respective months. It is not a proof, but Kepler surmised the annual repetition meant the earth's orbit around the sun was a closed orbit. Using inductive reasoning founded on God's perfect order, Kepler generalized that all planetary orbits closed on themselves.

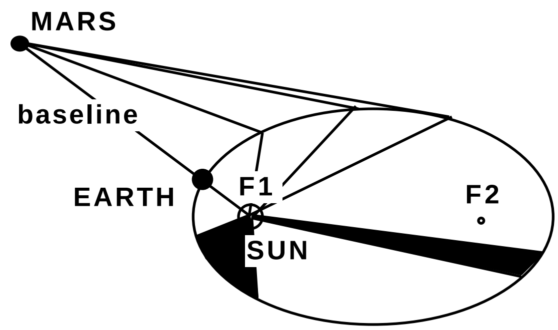

FIGURE 15.10 BY USING MARS AS A LIGHT BUOY IN SPACE KEPLER PLOTTED THE ORBITAL PATH OF THE EARTH. HE FOUND THAT PATH TO BE AN ELLIPSE WITH THE SUN AT ONE FOCAL POINT. HE ALSO SHOWED THAT THE EARTH SWEEPS OUT EQUAL AREAS IN EQUAL PERIODS OF TIME.

Using data collected over several centuries, the length of time for any given planet to move through space under the sphere of stars and return to the same place could be computed whether following Aristotle, Ptolemy, or Copernicus. This sidereal period was known for Mars as 687 days. Using the red planet as a buoy in the uncharted space, Kepler began with a time when Mars, the earth, and the sun formed a line and used that line as a base line. Knowing Mars returns to the same place every 687 days regardless of its orbit, the earth would make slightly less than two turns around the sun, thus being off the base line and a little behind its former position on the base line. Using triangulation between the sun and Mars from the earth, a triangle with the original base line could be drawn on a map that would be proportional in every way to the real triangle in space. Repeating this procedure using earth, Mars, and sun positions every Martian year of 687 days, a trace of the earth's orbit could be developed (FIGURE 15.10). Using mathematical techniques to determine the shape of that drawn orbit, Kepler found the earth moved around the sun with an orbit in the shape of an ellipse with the sun at a focal point. Kepler's first law for planetary motion as it is accepted today is a generalization of this for all

planets. It follows that during equal periods of time planets sweep out equal areas which is the second law of planetary motion. Finally, Kepler's third law by statistical analysis showed that the sidereal period of a planet squared is proportional to the third power of the major axis of that planet's orbit.

6. THE DISCOVERY OF LIMITS

In these golden years of discovery led by high Christian principles, great scientific achievements were made. The historical record showed amidst these achievements a lot of guess work, much error, circumstantial evidence, and always the uncertainty that follows assumptions. In Galileo's trial the Roman Church had taken a premature stand in defending so strongly the old paradigms of science with all of their weaknesses exposed by centuries of evidence. At the same time, the new world views in science had their weak points also. It must be recognized that nature created and maintained by God is rather silent about itself. None of the stars, the planets, the rocks, or the trees write or speak. The book of nature called science is continually being written and rewritten by human beings. Even in these very Christian dominated times of the sixteenth and seventeenth centuries, human beings remained subject to error and their science, however strongly tied to the Scriptures, always contained elements of human thought separate from His Word.

Francis Bacon (1561-1626), not to be confused with Roger Bacon, was a brilliant jurist, courtier, and parliamentarian of England. He was highly respected by King James I and in 1618 became Keeper of the King's Seal and Lord Chancellor. From this high office Francis Bacon wrote NOVUM ORGANUM in 1620 and declared intellectual independence from the old world of thought. He charged all readers of his work to begin anew, to separate themselves from Plato and Aristotle, from all authority, and rest knowledge only on reason or experience.

Francis Bacon's new scientific method contained three steps. The first was a complete immersion by the scholar in the facts setting aside all previous knowledge and allegiances to authority. In the second step, generally oversimplified in modern science textbooks, the scholar began a process of exclusion rejecting irrelevant material while testing minor hypotheses developed in the process. The exact processes were left to the scholar. Finally, by induction the investigator would arrive at general truths founded on the unbiased observations of the first step.

Growth of knowledge to Francis Bacon was like a pyramid, always building to a higher truth encompassing more and more at the base. At the same time Francis Bacon understood well the existence of error in human judgment. He identified four great classes of errors and called them idols which were falsely worshiped. Idols of the Theater were those errors arising from the influence of mere words over mind. Such errors came from outside a person's well-reasoned ideas when erroneous arguments persuade. Two classes of errors came from within a person. Idols of the Tribe were those errors generated when the research led a person to view more order in nature than actually existed. Idols of the Cave were those errors arising due to one's personal prejudices.

The fourth and worst of these false gods were the Idols of the Market Place. With these Francis Bacon had in mind all of the laws of science developed by Aristotle and also the great many more built upon those Aristotelian laws. The Idols of the Market Place have a following more widespread than just ideas from the ancient past. Every thought of mankind about the natural world comes to a person with a complete script of influences from many places. The market place is truly cosmopolitan. No individual can develop

science alone without influence from others. Science is a human endeavor and an especially collective endeavor. Greeks, Romans, Muslims, and Christians working in science have left imprints on their scientific thoughts, and they have also yielded to imprints from others. Errors anywhere in the historical chain of development are continually exchanged in the market place. No thought of a person is immune from such errors.

These idols are even carried in the inadequate words of language. Are there equants or focal points in space? Do words like gravity, planet, mammal, energy, field, or atom assist the understanding of nature or hinder it by limiting science? Words of the market place have their origins in both race and creed. As they are traded, errors of inadequate understanding and errors of unbelief are traded as well which is why Francis Bacon identified Idols of the Market Place as the worst.

Francis Bacon's NOVUM ORGANUM placed modern experimental science on a foundation of reason alone. Looking toward the hope of new successes in science, he also rightly showed the many idols of errors human beings were always plagued with. Greek science, invented to be separate from the Greek gods, was shown by Francis Bacon to be collapsing in every endeavor. The new scientific method built on reason alone would fail the same way following the same idols.

7. ISAAC NEWTON'S COMPLETED VIEW OF THE SOLAR SYSTEM

Just as Ptolemy's ALMAGEST gave the complete answer to many of the problems of classical motions in the heavens for the times of the ancients after several centuries of study, so did the PRINCIPIA written by Isaac Newton in 1687. Copernicus provided the model for the new solar system. Kepler formulated the elliptical laws, and Newton finally gave a physical reason for such motion. For the study of planetary motion, Newton generalized that motion everywhere in nature must be studied as changes from an inertial state which was a forward constant speed in a straight line. All such changes were brought about by interactions between a minimum of two bodies.

This two body view was drastically different from Aristotle's view who saw all motions coming from a "primary mover who did not move." Aristotle saw the primary mover impart motion on a body without a reciprocating influence on the primary mover. Newton's principle, invented in his mind, required interaction among bodies. If one body was seen as moving, another body somewhere had to be affected. Newton's universal law of gravity was an interplay of forces of attraction between a minimum of two bodies. The sun attracted the earth. The earth attracted the sun. At once the reason why the earth moved could be stated. The massive sun attracted the earth with a centripetal force of gravity pulling the earth into the sun. The comparative mass of the earth did the same equally and oppositely to the sun, but the resulting motion was seen as inversely proportional to the respective masses. The small earth experienced the greatest motion. The motion of the massive sun to the limits of measurement could not be detected. The forward high speed of the earth prevented the earth from actually being pulled into the sun. Coupling these two vectors of forward (tangential to the orbit) and radial (toward the sun) motions, Newton showed the orbit of the earth had to be an ellipse (FIGURE 15.11). Newton's universal law of gravity had shown also that the orbits of the planets had to be elliptical. The sun had to be at a focal point. The view of the solar system was complete. Reason for such heliocentric motion had evaded Copernicus, Galileo, and Kepler. Newton now could claim to know that reason.

Newton also invented a reflecting telescope which used mirrors instead of lenses. The

light gathering power of such a telescope was far greater than a refracting telescope. The reflector also did not have the chromatic aberration or color spectrum distortion that plagued large refractors. With this improved tool for observations, double stars were found and these stars also displayed motions explainable by Newton's universal law of gravity. The entire universe obeyed Newton's law.

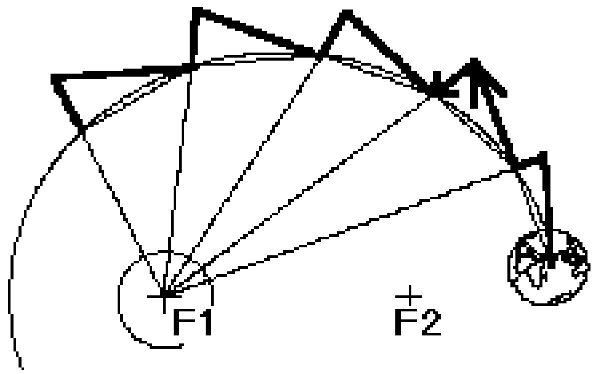

FIGURE 15.11 ACCORDING NEWTON THE EARTH SIMULTANEOUSLY FALLS TO THE SUN AS IT MOVES FORWARD TO GIVE ITS ORBIT AN ELLIPTICAL SHAPE.

All but Isaac Newton celebrated this great scientific achievement. His PRINCIPIA provided explanations for every motion in the universe, from controlled experiments in the laboratory to the distant massive stars. Newton knew gravitational forces were weak forces. How could the massive planets be moved by weak forces over such great distances? Space, for Newton, had to be a perfect vacuum. Aether could not exist. But if that were so, gravity had to be a force at a distance which was a force applied to an object without physical attachment. Such forces were accepted only in the occult. Newton was especially troubled by the fact that even with his new telescope he could not see heliocentric parallax, that opposite oscillatory motion which would demonstrate the earth's motion. Ultimately Newton's explanation of planetary motion failed to give efficient and final causes. Forward inertial motion kept the planets from being pulled into the sun, but how did such motions get started and why?

This new age of science had serious problems from its beginning that remained unresolved. Publicly Newton frequently stated, "I frame no hypothesis . . ." ("General Scholium," Second Edition, PRINCIPIA, 1713). Yet in private letters he debated unceasingly with Gottfried Wilhelm von Leibnitz about the role God played in nature. Leibnitz, in a Calvinist tradition, argued for perfect unalterable order in nature as in a perfect clock where the all-knowing God preordained all things from creation. Newton, a believer in absolute measurements and a discoverer of unalterable laws, argued for an all powerful God with mercy who had the power to intervene and answer prayer. These great theological ideas cannot be reconciled by reason alone. Yet they are intimately part of the natural world and thus must remain part of the human explanation of nature which we call science. One can understand in troubled religious times, when long brutal wars were fought between Protestants and Catholics, why Francis Bacon and Isaac Newton may have desired to keep religion out of the laboratory. The Christian was plagued with unresolved problems and errors in his science, but this sudden turn to remove religious imprints from explanations of the natural world would give a kind of science no one was prepared for.

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SEPARATE FROM HIS WORD

FINAL CAUSES OF NATURAL THINGS:
A Triumph in Science for Christians, Chapter 16

Coincident with the discoveries that shattered the Aristotelian crystalline spheres were works of Christian men like William Harvey and Robert Boyle, Englishmen who changed the studies of human anatomy, physics, and chemistry. Christian faith sees a gracious God. Reason guided by faith understands that all things in nature were created with purpose and with order. The knowledge that God provided order gave science a most exciting revolutionary century. One ancient pagan idea after another, founded on a separation from the gods, was replaced by new ideas from men of the Christian church who could behold the wonders of nature and praise the Triune God for wondrously making all things.

1. WILLIAM HARVEY AND THE "NEW" HEART

One such discovery founded on a faith in created order was the circulation of blood pumped through the body by the heart. The accepted medical science of the day followed the writings of the surgeon of the Roman gladiators, Galen (A.D. 131-201). Galen saw two separate blood vessel systems. He thought each system, the arteries and the veins, contained different blood. The heart distributed vital spirits in the blood of the arteries, and nourishment was distributed by the liver in the blood of the veins (Science under Roman Rule, Chapter 10). Both bloods moved outward from the liver and the heart and were consumed by the body. It was obvious that the vessels got smaller and smaller as they were traced farther from their source.

William Harvey noticed valves in the veins similar to those that existed in the arteries. The venous valves were oriented in the opposite direction from the Galen model of blood flow. Knowing God created all things with purpose, William Harvey was troubled with the idea that the venous valves could not serve a purpose when oriented in the opposite direction from the blood flow. Structure in God's creation had purpose and when structures were similar, to William Harvey that meant their function was similar. Both the right ventricle and the left ventricle of the heart were of the same structure. Except for a slight darkening of the blood in the veins, Harvey saw no difference between the two Galen types of blood. He reasoned the close proximity of the lungs to the heart also must serve a purpose in God's design for His creature (FIGURE 16.1).

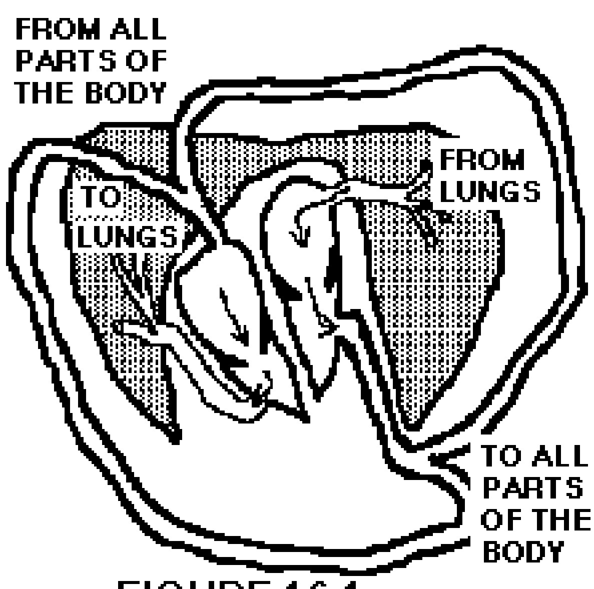

FIGURE 16.1
THE CIRCULATION OF BLOOD.

With this new revolutionary view Harvey began to put together a new understanding and saw a reason for an interdependence of blood, heart, veins, arteries, and lungs. He noticed one system of arteries and veins spread out from the heart to the lungs, and a second system of arteries and veins spread out to the rest of the body. This disproportionate distribution seemed illogical without a designed purpose. By viewing blood vessels in pairs, Harvey showed his early intellectual commitment to a blood circulation. Blood circulating by action of the heart as a mechanical pump and not as a producer of arterial blood was a sudden brilliant conclusion that gave answers to the many previously raised questions and also to many more. There existed one and only one kind of blood, and it circulated through the entire body bringing fresh air from the lungs which surrounded the heart to all parts of the body. The darker venous blood, with used air, entered the heart through the vena cava, was pushed by the muscles of the right atrium through the tricuspid valve into the right ventricle, and was again pushed by the heart pump through the pulmonary valve into the pulmonary trunked arteries to circulate through the lungs to exchange air. Bright red blood filtered into the pulmonary veins and into the left atrium where again muscles of the heart pumped blood refreshed with air through the mitral valve into the left ventricle. From there it went out the aortic valve through the aorta to be distributed throughout the body by arteries and again return to the heart by the veins. This circulatory system gave a purpose to the venous valves and an explanation for the perfect design relationship between heart and lungs.

With an understanding of circulation theory, William Harvey began dissection of living animals. He determined the rate of blood flow past a given point in the circulation system of an animal, and simple mathematics showed more blood passed such a point in less than an hour's time than the weight of the entire animal. This demonstrated how unreasonable the Galen view of blood being generated by the heart really was. An animal could not produce and consume such an immense weight of blood when its diet and excreted waste was comparatively small.

Harvey published his work ANATOMICAL TREATISE ON THE MOVEMENT OF THE HEART AND BLOOD IN ANIMALS in 1628. His views were not readily accepted. The actual relationship of air to blood was not completely understood. The element fire or phlogiston was believed to be exhaled as foods were consumed in a body. Harvey provided no answer as to how arteries might be connected to veins. That would come from an amateur Dutch lens grinder, Antony van Leeuwenhoek (1632-1723).

Leeuwenhoek lacked formal education as a scientist and did not practice systematic order in his observations. However, motivated by a lively curiosity and through the use of a homemade microscope he witnessed blood capillaries linking arteries to veins and reaching every part of an animal's tissue. He found red blood corpuscles of fish, frogs, and birds and the distinguishing disc-shaped red blood corpuscles of humans and mammals. He also discovered the relationship between sperm and eggs. He found parasites and bacteria, but many of these findings were ignored by the established scientific community for more than a hundred years. However, his discovery of capillaries completed Harvey's blood circulation system and was made known to the Royal Society by 1673.

The more the magnificent body our Lord has given us is studied, the more complex it appears to be. William Harvey, standing in awe of the wonderful works performed by his Creator-God, could with greater insight truly sing with the Psalmist:

For you created my inmost being;
you knit me together in my mother's womb.

I praise you because I am fearfully and wonderfully made;
your works are wonderful,
I know that full well.
My frame was not hidden from you when I was made in the secret place.
When I was woven together in the depths of the earth,
your eyes saw my unformed body.
All the days ordained for me
were written in your book
before one of them came to be.
How precious to me are your thoughts, O God!
How vast is the sum of them!
Were I to count them,
they would outnumber the grains of sand.
(Psalm 139: 13-18, NIV)

2. THE SKEPTICAL CHEMIST, ROBERT BOYLE

Robert Boyle was the son of the wealthy Earl of Cork, and he was the seventh child in this family of fourteen. At an early age he was given a tutor from France and traveled extensively with him. He even studied the works of Galileo right in Florence. As a Protestant young, man he vacillated between his love for science and his love for church and country. The Boyle family Lismore Castle was a frequent house of refuge for Protestants facing Catholic persecutions. Robert Boyle desired to join various military causes and was always prevented from doing so by requirements of the family who controlled the purse of its members accustomed to a life of leisure. During much of his life, Robert Boyle's country and church were in turmoil. England fought several skirmishes both on land and sea with France, Holland, and Spain over influence in Europe and for dominance of trade with their respective colonies in the Americas and the East Indies. Turmoil in the religious world also became mixed up in both national and international politics. The Catholic-Anglican church of England politically supported the king of England for its own political gain. Protestant groups found political power in Parliament, while among themselves, they were being torn apart by the Puritan movement. In Robert Boyle's lifetime Parliament was dissolved and reinstated many times and King Charles I was executed. A short-lived Commonwealth of England came into existence under the leadership of Oliver Cromwell. When the crown was restored, Parliament required an oath of allegiance to the Protestant faith excluding non-conforming Puritans and Roman Catholics. A plot was uncovered in which the Vatican had secretly ordered the assassination of the King of England in order to gain Catholic dominance. Despite all this turmoil family wealth permitted Robert Boyle a life of leisure to pursue basic research in the natural sciences.

The barometer presented one of many intriguing problems of seventeenth century science to capture the interest of Robert Boyle. Evangelista Torricelli (1608-1647) had invented the barometer by taking a long glass tube, melted shut at one end and open at the other end, filling it with mercury and inverting it into an open dish of mercury. The mercury came down a little way in the inverted tube but did not empty. A column of mercury remained nearly thirty inches high. Only a small portion of the closed end of the tube above the column of mercury remained empty. The explanation given by Torricelli is the one given in our time-- that the space in the closed tube above the mercury was a vacuum. When comparing a vacuum of nothing, which has no capability of exerting a force, to the ocean of air pressing down with a force in every direction, the imbalance of forces held up the column of mercury. The atmosphere was seen as giving a pressure down on the surface of the mercury in the open dish and pushing mercury up into the

tube to a height of nearly thirty inches until equilibrium was reached (FIGURE 16.2). The pressure of the mercury in the barometer tube exactly equaled the pressure at the bottom of the ocean of air in which we live.

Blaise Pascal tried to demonstrate the effects of changing the imagined air pressure on the barometer by climbing Puy-de-Dome, a mountain in central France, carrying the pressure detecting device. To Pascal the barometer showed a high pressure at the base of the mountain when he stood at the bottom of the ocean of air, and as he climbed higher into the air, with less and less air above him, the air pressure went down and the column of mercury in the barometer went down also.

We see in this scientific study of pressure an inductive development of thought. Generalizations were made from a few observations. In such cases, uncertainty always remains a problem. Aristotle's warnings, both against inductive reasoning and the existence of a vacuum, always remained real. Opposition to physical explanations involving vacuums was strong. Galileo had developed an explanation of ideal motion predicated on movement in a vacuum (Chap. 17) without air resistance. His explanation did not need a real vacuum while Boyle's explanation of the barometer did.

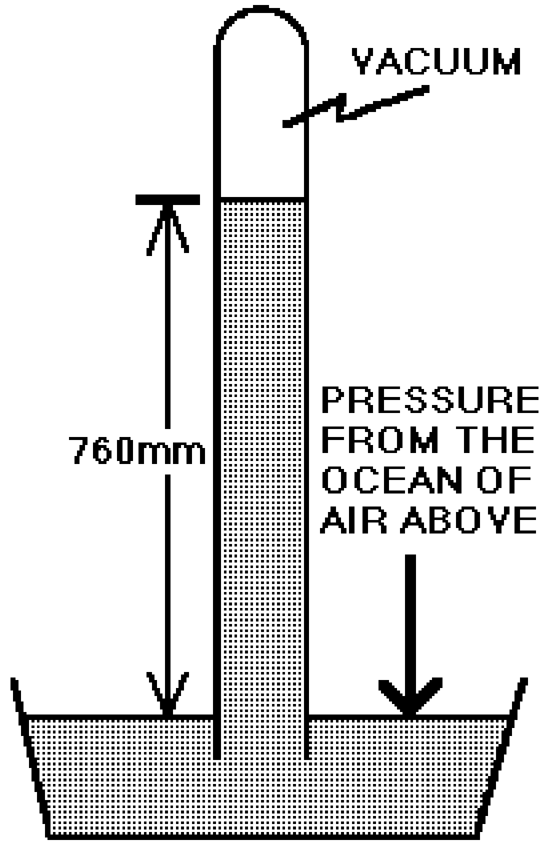

FIGURE 16.2 A MERCURIAL BAROMETER.

Other explanations for the support of the column of mercury were developed. One such explanation came from Franciscus Linus, a Jesuit committed to Aristotelian anti-vacuum views. Linus claimed funiculus fibers between the closed top of the glass tube and the mercury held up the mercury. The natural breaking limit of the fibers was slightly beyond the weight of thirty inches of mercury and this gave a reason for the height of the column of mercury. The pull of funiculus fibers could be felt by a finger tightly pressed to the top of a vertically held tube filled with any liquid and open at both ends except for the observer's finger.

Robert Boyle developed a demonstration to counter the argument against vacuums by attacking the existence of funiculus fibers. He took a glass tube melted closed on one end and kept the other end open. He made this tube much longer than a typical barometer tube. Bending the tube in the shape of a "J" with the short end being closed and the long end open, he began pouring mercury into the tube. The open end could not support funiculus fibers. The closed end had air, not a vacuum, trapped by the mercury. Quite accidentally he thus discovered the law of science that now bears his name in which it was shown that at constant temperature, as the air was compacted in the "J" tube by adding more and more pressure made by the addition of mercury, the volume of a gas was inversely proportional to the pressure on that gas (FIGURE 16.3). But Boyle

was not interested in this law. He continued his work. By adding his known atmospheric pressure of nearly thirty inches of mercury to the other eighty-eight of actual mercury, Boyle showed the compressed air in the "J" tube indeed could support more than four times the column of mercury supposedly held up by funiculus fibers. The "spring in the air" had the ability to give a pressure.

Not until Robert Boyle, following the new laboratory procedures established several centuries earlier by Robert Grosseteste, could construct a vacuum pump together with a bell jar and perform experiments under controlled pressure changes could the concept of vacuums be accepted. A barometer simply could not work as explained unless a vacuum was demonstrated as real. In his receiver or bell jar, with air drawn out of it by his pneumatics engine or vacuum pump, Robert Boyle could show the rise and fall of mercury in the barometer to be directly proportional to the amount of air pumped out. He also showed the dependence of sound on the medium of air. A bell could not be heard ringing with no air present.

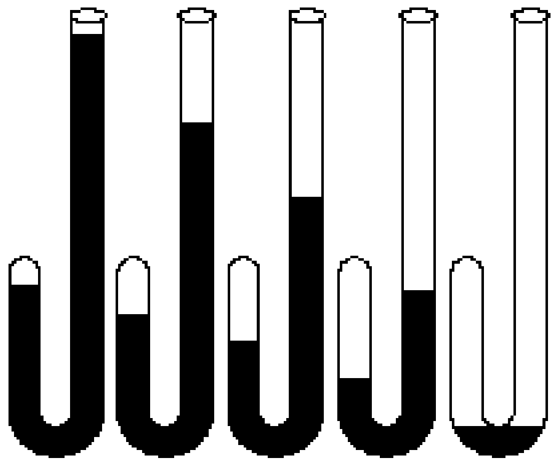

FIGURE 16.3 A COMPARISON OF "J" TUBES SHOWING BOYLE'S LAW.

Thinking light needed a medium for transport as sound did and observing that light remained in the bell jar even after as much air as was possible was pumped out of the bell jar, Robert Boyle reasoned luminiferous aether must still be in the bell jar in large quantities. Aether was known to be subtler than air and could readily flow through many dense materials such as the glass of the bell jar. To detect the presence of aether, Boyle developed one ingenious experiment after another. Using different devices controlled from the outside of the bell jar, Boyle could manipulate moving parts within the bell jar. He tried to concentrate aether in a small enough space to give it sufficient force to be detectable. One such device was a simple arrangement of feathers that would spin when falling through aether. Another was a set of bellows that when closed concentrated the aether in a narrow tube to blow against a feather. Other piston arrangements concentrated aether against feathers or forced the aether through a liquid in the hope of forming aether bubbles.

In all these experiments, much air was pumped out of the bell jar. In all cases the devices within the bell jar, which was still suspected of containing aether, failed to show the presence of aether. This was the first major direct experiment in the modern era to test the existence of one of the five ancient elements. However, the hardest thing for science to demonstrate is the non-existence of something. Boyle could conclude he could not detect the presence of aether. He could not say there was no aether and neither can we.

Inductive reasoning, supported by laboratory demonstration, was a powerful tool. Nevertheless, discovery with certainty, beyond all reasonable doubt, could not be achieved. Leaks in the receiver and pneumatics engine always existed. The very fact that the pneumatics engine worked by allowing air in the receiver to expand into an exhaust

piston only meant that the air was diminished by a percentage of the remaining air. A true vacuum was unobtainable. But science grows with confidence, not certainty. That confidence gives a trust, not a truth.

No laboratory in Europe could perform Robert Boyle's experiment exactly. A great many anomalies existed when comparing pressure data gathered in France, Switzerland, Germany, or Italy. Only with the invention of nearly instantaneous mass communication would the unexplainable pressure anomalies be seen as the actual waves in the ocean of air. High and low pressure systems in World War I were mapped and their motions monitored in war-like frontal clashes. These unexplainable "errors" that plagued Boyle led the way to modern weather forecasting.

Two interesting characteristics of the development of scientific thought are clear with Robert Boyle's work. First, his discovery of the inverse relationship between pressure and volume was quite accidental. He was not looking for it. At the time his only desire was to demonstrate the non-existence of funiculus fibers. Accidental stumbling upon interrelationships in nature which lead to the laws of science is a common occurrence. Development by accident cannot be prepared for, it cannot be planned, and it cannot be predicted. Frequently such accidental discoveries change the entire direction of research, and were it not for such accidents, the laws of science could conceivably be quite different. It has already been shown many times that different explanations work for similar data.

The second interesting characteristic is the role of error in scientific development. It must be realized that errors alone rarely lead to rejection of scientific theory. The concept that we live at the bottom of an ocean of air which causes the air pressure was not rejected even though every laboratory recorded different absolute measurements of pressure. Only partial or trending agreement of pressure differences existed, such as the change of pressure over a drop in height of a similar distance. A common strength in all of the sciences is its capability of existing with the tension of unexplainable error and eventually using the errors as confirming evidence at a later time. Pressure differences showed the actual waves on the ocean of air. The failure of Copernicus, Galileo, and Newton to see heliocentric parallax, rather than refute the theory of their solar system, confirmed the immensity of the universe, placing the stars so far away so as not to give witness to oscillating motions among the stars. In ancient times, the condemning nothingness between Democritus' atoms became the empty space necessary for any and all motion to occur. In modern times, failure to find great quantities of missing links in evolutionary development of species confirmed for many scientists the extinction of transitionary species as well as providing evidence for many scientists that there were incredibly long periods of time reaching way past recorded history and the written record of the biblical creation. Always the human reason of the practitioners of science stands as both judge and jury over the role of errors. Whether errors will condemn a theory or be left eventually to support the theory rests on the faith and trust the scientists themselves have in their given explanatory models or paradigms for nature.

3. ROBERT BOYLE AND FINAL CAUSES

One of the more exciting works of Robert Boyle was his DISQUISITION ABOUT FINAL CAUSES OF NATURAL THINGS published in 1664. The Christian teacher is concerned with teaching all things in the light of God's Word ". . . believing that man as the crown of creation was endowed with gifts that permitted him to become acquainted with, enjoy the

use of, and find cause for wonder and gratitude in everything that God fashioned for human service and delight." (A Statement of Purpose, DMLC Catalog, 1986-87) For such a teacher Robert Boyle's views as a Protestant and a scientist with deep religious convictions are invaluable. He leaned on the knowledge of the four causes defined and identified by Aristotle and stressed the special role of understanding the final cause in the study of nature. Remember, final causes deal with the motives of the maker of things and answer why he made things as he did. Also in nature, final causes must deal with the motive and purpose God had in mind. Robert Boyle boldly claimed all studies about nature, all science, must search for and find final causes. Final causes were most visible in the study of the structure of the bodies of animals. An example of the success of such realizations of God's purpose and design in the structure of living animals was the great discovery of blood circulation and the interrelationship between the heart and the lungs by William Harvey.

Robert Boyle recognized limitations for the scientist in understanding final causes for all things. He recognized as especially difficult the identity of final causes for things in the domain of the physical sciences. Non-living stones and metals did not reveal such final causes without lending wild speculation to such causes. Nevertheless, the scientist's inability to find such causes in the physical sciences did not eliminate the fact that God, the Designer of all things, indeed had a motive for rocks and metals when he created and made them for mankind. Such final causes led Robert Boyle to write THE SCEPTICAL CHYMIST in 1661 where he questioned the role of fire as an element. Everywhere in experience fire was seen in a destructive role. God's planned use for fire at the end of the world likewise was destructive. An element was expected to be a forming building block. His use of Christian interpreted final causes led him to doubt the existence of fire as an element. Robert Boyle also failed to find aether with his pneumatics engine. Such skepticism paved the way to a rejection of the five elements dating back to Empedocles and the Pythagoreans and laid the foundation for the new chemistry of Lavoisier and Dalton in the next centuries.

For the Christian, Robert Boyle gave warnings with respect to asserting a knowledge of final causes in physical science. They are good warnings for us. First we dare not be too hasty reaching conclusions or too insistent on certainty with respect to our interpretations of final causes. We can be bold about God's final cause for the rainbow. He told us in the Holy Scriptures His motive for placing the bow in the sky.

And God said, "This is the sign of the covenant I am making between me and you and every living creature with you, a covenant for all generations to come: I have set my rainbow in the clouds, and it will be the sign of the covenant between me and the earth. Whenever I bring clouds over the earth and the rainbow appears in the clouds, I will remember my covenant between me and you and all living creatures of every kind. Never again will the waters become a flood to destroy all life. Whenever the rainbow appears in the clouds, I will see it and remember the everlasting covenant between God and all living creatures of every kind on the earth." (Genesis 9:12-16, NIV)

At the same time we cannot say with certainty God's purpose for many other physical phenomena. We have forty-two chapters of the book of Job where Job and his visitors struggle with God's motive and purpose for Job's suffering. Job is told by God, through rhetorical questions from God Himself which Job could not answer, to trust His wisdom. However, Job was never told of God's motive and purpose for dealing with Satan, of which Job's losses and suffering were only a small part. God's final causes for the natural world are not given. All of us as sinful people on our own cannot claim to know them.

Robert Boyle also warned that we dare not be slowed in our pursuit of knowledge about

physical science just because we cannot be certain of final causes. The excitement of science should not be hampered by our weaknesses, our mistakes, or our failures. The excitement of pursuing an understanding of nature lies in the certain knowledge that God knows His final causes for the natural world He has made and we know Him.

Robert Boyle's DISQUISITION ABOUT FINAL CAUSES OF NATURAL THINGS represents a high point in Christian contributions to science. It shows what can be accomplished knowing that our Heavenly Father created all things with order and with purpose. At the same time Robert Boyle shows some insurmountable obstacles which the wisest person, Christian or pagan, cannot climb concerning God's purposes with the natural world. These failures to comprehend all of God's purposes and design for nature are really not barriers in a negative sense. In the pursuit of scientific knowledge, when humility is learned, the Christian also learns of the wisdom and power of his Almighty God.

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SEPARATE FROM HIS WORD

THE UNIVERSAL LAWS OF MOTION:
Reason Alone, Chapter 17

Christian principles provided much direction to scientific development, but Christians quickly displayed their human sinful limitations by struggling against each other for economic, political, and national dominance. The times following the Reformation in both Europe and England were filled with trials and judgments of heresy in the church and of treason against the state. Facing such a judgment of heresy and its penalty of torture on the rack, Galileo Galilei recanted his astronomical work and devoted the rest of his life to the study of mechanical motion on the earth. Perhaps because of his bitter experience with his church and the threat against his life by the established political powers of his church, Galileo turned to reason alone for his explanations of nature. Sticking to reason alone, he avoided contested struggles from opposing groups vying for allegiance to a particular faith. By confining his research to simple moving objects, he tried to avoid controversy. Finally, using pure reason to explain non-controversial items, Galileo felt that a person could rise above faith or religious beliefs.

1. GALILEO ESTABLISHES PRINCIPLES OF UNIFORMITY

Turning to reason alone, Galileo developed the concept of inertial motion quite different from the explanation Aristotle gave motion which was still taught at the universities in Galileo's time. As a result, Galileo caused a far greater revolution in physics than he could have in astronomy, but it took longer to understand his new physics. Galileo began in the abstract, in the ideal, like Plato would have begun. He looked at the imaginary vacuum and tried to visualize motion in such an empty imaginary place. To avoid controversy, Galileo was quick to point out that he did not really need a perfect vacuum. No vacuum was really expected to be found in nature. In such an ideal state, however, objects could fall without the influence of air. Galileo recreated many of his ideal concepts in the laboratory following a scientific tradition of demonstration established by Robert Grosseteste.

Galileo used the laboratory beyond mere demonstration. In an effort to understand a rapidly occurring event such as free fall, he used inclined planes to extend the time of fall, thus using the laboratory for exploratory purposes. He discovered that during the free fall of an object, the velocity changed. By defining acceleration as the change of velocity with respect to time, he had invented a change of a change. Using heavy spherical objects that could roll nearly frictionless, Galileo simulated motion in a vacuum. The acceleration for free fall turned out to be constant. The velocity of a free falling object in a vacuum would steadily increase by the same amount in each successive equal period of time indefinitely. The distance traveled in free fall increased proportionately to the square of the amount of the time of falling. Aristotle's objection to free fall in a vacuum, which he claimed would reach an infinite speed, turned out to be in agreement with Galileo's ever increasing velocity if given enough time. But Galileo really did not care if a vacuum existed or not. Alterations because of the presence of air could be added to Galileo's science of motion as complexity for an advanced study. This was Galileo's new science.

Galileo's use of Platonic ideals, using pure reason permitted an understanding of nature beyond the senses in an abstract sort of way. At the same time, experiments in the laboratory or experience following Aristotle's actuality prevented pure reason from

becoming lost in abstraction. The real world was not a shadow as it was to Plato, but instead the ideal presented an image. Frequently these two approaches, the abstract or theoretical versus actual measurement in the laboratory, provided a tension that could lead to an understanding of highly complex phenomena in nature. It remains true that Aristotle's description of heavier objects falling faster proportional to their weight is closer to the way objects actually fall. The study of free fall, being quite complex, however, could not grow beyond Aristotle's views. Galileo used his new methods to provide a new hope of expanding knowledge. Isaac Newton added increasing forces of air friction to oppose the constant force of gravity in solving the problem of free fall in air for the next generation of scientists.

To convince men of science of the value of his new approach to science, Galileo performed a public demonstration by dropping two spherical cannon balls from the top of the tower of Pisa, a distance of eight floors. One cannon ball weighed ten times heavier than the other. The two cannon balls, in spite of their weight difference, appeared to slice through the thin air as though it were a vacuum and hit the ground precisely at the same time. Such a demonstration gave confidence in the new explanation and cast doubt on Aristotle's careful observational work in which he compared rates of fall of varying sizes of eggs falling through liquids. Had Galileo dropped his cannon balls from the Sears Tower in Chicago, Aristotle's view would have been confirmed. Dropping cannon balls from a much taller tower would permit a greater time for the influence of the air friction to be seen on the smaller cannon ball. Heavier objects do fall faster in air than lighter ones, even cannon balls, if given enough distance to fall. A clever Galileo chose his observations and experiments for demonstration in a very effective and convincing manner. The exact mathematical results for motion, in which the resistance from the surrounding media was negligible, also added to the scientific prestige of Galileo.

Galileo developed another powerful tool of reasoned abstract physics called inertia. Today, Galileo's views of inertia have become Newton's first law of motion. For the record, the trivial case must be mentioned, that "things at rest will remain at rest unless acted on by an outside force." This law of motion says nothing more than to state the fact that motionless objects cannot begin to move of their own accord. The other part of Newton's first law of motion explains a constant motion without end. "Things in motion will remain in motion along a straight line at a constant speed, unless acted on by an outside force." This statement radically separates the physics of Galileo from the physics of Aristotle. Galileo was saying that if an object was already moving, it could never stop moving, it could never change its speed, and it could never change its direction unless a force was applied to cause that change. Aristotle's physics described the actual world, and in that actual real world, all objects which once moved quickly slowed down and came to a stop. Aristotle could not possibly describe a motion of any kind unless a force was involved. In Galileo's world of physics the force was on the outside causing change. Such a world permitted friction, but only as an addition. First, a frictionless world which did not exist must be studied. Again the ancient Greek was closer with his explanation of actual motions in a real world. However, Galileo's physics permitted the study of friction as an outside force slowing down a moving object that rightfully should never stop moving. Again the new age saw new hope for Galileo's new science.

Central to Galileo's new physics was the idea that laws governing natural order worked everywhere. Throughout the entire universe all objects would obey Galileo's law of inertia. At this time, when Aristotle's view of the existence of a great gap in nature with different laws governing the celestial world than the terrestrial world dominated, Galileo's universal uniform view was very new. Through reason, inertial motion occurred everywhere and could be explained everywhere the same way. Planets in the universe moved the same way as marbles in a laboratory. Forces causing motion of objects and

machines in the physical world were similar to forces causing motion by animals in the biological world. These spanning views of Galileo bridged a second great Aristotelian gap. Galileo wrote of various forces and proportional strengths for bones of living creatures following the same reasoning he used for forces for non-living things. These mechanical views of all things everywhere were published in 1630 under the title DISCOURSES CONCERNING TWO NEW SCIENCES.

Using theory of forces and levers, Galileo showed that it was impossible for animals with the ability to move at high speeds to increase their sizes proportionately and keep their agility. In his proportionality equation, he stated that increases of an animal's weight were proportional to the cube of their length. An animal twice as long would have to have a weight eight times heavier than the starting standard, but muscles would become only four times stronger for the given standard. Eventually the animal would not be able to move the weight needed to support the animal's size. Galileo found in nature a certain optimum size for each of the species. Such limits of growth showed sea creatures had the ability to grow to the greatest sizes according to Galileo's science.

2. RENE DESCARTES AND REASON

Rene Descartes (1596-1650) was born in France, trained in a Jesuit school as a dedicated Roman Catholic, traveled over much of Europe, and finally settled in Holland. As a well educated innovative thinker Descartes had been extremely successful merging geometry and algebra, forming a powerful new mathematics called analytical geometry and trigonometry which allowed for the sweeping certain conclusions of geometric theorems to yield precise solutions calculable by algebra. He saw lines not as connecting rays between points, but as a locus of points of positions of moving objects.

Descartes was a believer in the Copernican solar system and was in the process of writing his own TREATISE ON THE WORLD when in 1633 he learned of Galileo's conviction of heresy. Being a Catholic in the tumult of the counter-Reformation, Descartes suddenly decided not to publish his work on the motions of the world until he felt he could find a reasonable explanation overcoming his church's objections. Like Galileo, Rene Descartes turned to reason alone in order to avoid charges of heresy by the inquisition. In 1641, while in Paris, Descartes wrote MEDITATIONS ON THE FIRST PHILOSOPHY. In this work he argued by reason alone, even for the existence of God.

Once the mind has moved to seek answers by reason alone, inevitably God as Creator and Sustainer is left out. Multiple causes, such as those expected by Aristotle and promoted for the natural sciences by Robert Boyle, although not rejected by Descartes, were at least set aside and not pursued. Rather, Descartes continued to pursue an understanding of all motions by reason alone by reducing every natural phenomena to some mechanical explanation. He saw all motions as some type of circular motion. He rejected a vacuum because he reasoned that as an object moved, other substances circled around it, exactly filling in behind the first object of motion without ever forming a vacuum. His picture for the entire universe was one unified collage of vortexes. All sorts of shapes and sizes from large bodies, such as planets, to very small particles invisible to the human eye moved at different speeds and with differing frictions giving nearly an infinite variety of vortex motions. Among all the vortexes three forms of matter existed. One kind of matter tended to move in an individual vortex to the center of that vortex. Some particle forms of matter moved away from the center of a vortex radially to the circumference of the vortex. These particles were a second form of matter, usually transparent as air. These outwardly radial moving particles caused gravity as an equal but opposite reaction. The transparent matter moving outward equally and oppositely moved

larger visible objects downward toward the earth. The earth and other planets were large opaque bodies which formed the third kind of matter. They simply were carried along within each of their own vortexes. This was the way Descartes developed an acceptable Copernican explanation for the Roman Catholic Church. The earth could remain immovable in the vortex while the vortex carried it around the sun.

With Descartes' gravity we see Newton's third law of motion as it is accepted in our modern times. "For every action there is an equal and opposite reaction." Descartes also discovered another interpretation of that law which we now call the conservation of momentum. The summation of the momentums (mass times velocity) of the bodies before a collision must equal the summation of the momentums of the bodies after collision no matter how the bodies might be rearranged by the vortexes that caused the collisions.

Anaxagoras was the first to establish a law of conservation, and he did so eliminating the Greek gods. By reason alone all scientific laws of conservation can never be worked back to a beginning or a creation. They logically reached conclusions of a material existence such as Democritus' atoms which were eternal and uncaused. At least Descartes claimed the Triune God created the initial momentum and from that creation no loss or gain of momentum was ever possible. That is a reasonable interpretation for Christians to give the laws of conservation. With respect to matter, God alone created all matter and since that creation no human being can destroy any matter, but they can use it and change it. Likewise, we never lose momentum. When an observer experienced an apparent loss of momentum, there really was no loss. That momentum was transmitted to the fine transparent particles not visible. Descartes' vortexes paved the way for ceaseless kinetic molecular motion which would be so similar to Democritus' atomic motions.

3. RELIGIOUS STRIFE DIRECTS MEN OF SCIENCE TO REASON ALONE

While men of science such as Galileo and Descartes had their writing subjected to censorship by the dominant Roman Catholic Church, in Protestant England religious strife among different groups who each demanded political allegiance took its toll on intellectual freedom. The Church of England, independent from Rome, struggled with the Separatist movement, fought Presbyterian reform, and led the nation into civil war over the Puritans. The universities found their respective faculties taking sides. The University at Oxford became a stronghold of the king, and, when Cromwell came to power during the Commonwealth years, he made himself chancellor of that university. The University of Cambridge became a stronghold of Puritanism.

Robert Boyle sought academic freedom in the "Invisible College," a group of independent scholars dedicated to experimental philosophy which met in London starting in about 1645. Robert Boyle, with religious controversy all around him and with his fellows of the "Invisible College" trying to avoid religious controversy for the sake of free and open pursuit of science, insisted efficient and final causes with all of their religious overtones had a place in the scientific study of nature. For Boyle, part of academic freedom was to be free to expound his own religious beliefs. When the "Invisible College" became The Royal Society for the Improving of Natural Knowledge by Experiment, Robert Boyle refused its presidency. The Royal Society, in an effort to avoid controversy and maintain patronage from the king, confined itself to strict mathematical demonstrations and laboratory experiments. This society dedicated to discovery by reason alone proved to be a fruitful seedbed for science for Isaac Newton, the inventor of unified physics.

Isaac Newton, a Puritan at Cambridge, was always cautious in his country where the educated Puritan clergy frequently lost their positions by official decree. He published very little before being admitted to the Royal Society where his public view "to frame no hypothesis" about efficient and final causes for nature could be promoted and his unifying views of science could be published without religious critique.

4. ISAAC NEWTON AND FLUXIONS

Newton, working with changing slopes of curved lines on graphs and areas under such curves, discovered an entirely new system of mathematics which he most accurately called fluxions because of the ability of this new mathematics to deal with fluctuations or changes. If nature had been created as the Muslims viewed Allah, algebra would have been sufficient. However, Newton saw nature as an ever changing creation. Algebra cannot deal with continual change. Standing on the shoulders of Galileo, Newton saw that all nature must be studied as changing from some preconceived status of inertia. Galileo had defined velocity as a change of distance with respect to time and acceleration as a change of velocity with respect to time. Newton redefined these physical properties in terms of fluxions or the calculus. Velocity became a derivative of distance with respect to time,

$$V = \frac{ds}{dt},$$

and acceleration became the derivative of velocity with respect to time,

$$A = \frac{dV}{dt},$$

or the second derivative of distance with respect to time,

$$A = \frac{d^2s}{dt^2}.$$

With this new tool of the calculus Newton could demonstrate that the many algebraic formulas for ideal frictionless motion, which many prep students of physics must memorize and struggle with, could suddenly be generated from the simple definition of acceleration by mere integration of the derivatives.

The mathematics shown in this paragraph is given in the modern notation, not Newton's, but it serves to show how manipulation of terms can give the formulas which were so long struggled for empirically.

$$A = \frac{dV}{dt}$$

$$\int_{V_i}^{V_f} dV = \int A\,dt$$

$$V_f - V_i = At + C_1$$

Since V_f, the final velocity, equals V_i, the initial velocity, at the starting time of zero, the integration constant in this simple case may be dropped.

$$V_f - V_i = At,$$

is a common memorized equation of motion.

Continuing with the definition of velocity,

$$V = \frac{ds}{dt}$$

$$V_f = V_i + At = \frac{ds}{dt}$$

$$\int ds = \int (V_i + At) dt$$

$$s = V_i t + \frac{1}{2} At^2 + C_2$$

Again boundary conditions for a simple case shows distance S equal to zero when time is zero and the second integrating constant may be dropped.

$$s = V_i t + \frac{1}{2} At^2$$

is another common equation of motion.

These few steps of calculus might be lost on a novice to mathematics, but they are given here to show the power of the new tools given to the scientists by Isaac Newton. He could attempt to describe any and all motions with mathematical models. The calculus could follow changing velocities, changing accelerations, and many more multiple changes over the several dimensions.

A formula known to Robert Boyle, P = Dgh (where P is pressure, D is density, g is the acceleration due to gravity, and h is the height of the substance applying the pressure) gave very shallow heights to the ocean of air under which we all live. If the density of air is taken as 1.129 Kg/(M cubed), g as 9.8062 M/(sec squared), and using the standard air pressure at sea level as 101,300 Newtons/(M squared), then the height of the atmosphere can be calculated to be 9150 metres or only 5.7 miles compared to a real atmosphere with a height greater than thirty miles. But the density of air changes with height and so does the acceleration due to gravity. Newton's calculus could deal with such changing values.

If we continue in this mathematical spirit, the simple definition of acceleration today can be expanded, for motions in air as an example, into many terms just for one dimension.

$$a_x = \frac{dU}{dT} = \frac{\partial u}{\partial t} + \frac{\partial u'}{\partial t}$$

$$+ \frac{u \partial u}{\partial x} + \frac{u \partial u'}{\partial x} + \frac{u' \partial u}{\partial x} + \frac{u' \partial u'}{\partial x}$$

$$+ \frac{v \partial u}{\partial y} + \frac{v \partial u'}{\partial y} + \frac{v' \partial u}{\partial y} + \frac{v' \partial u'}{\partial y}$$

$$+ \frac{w \partial u}{\partial z} + \frac{w \partial u'}{\partial z} + \frac{w' \partial u}{\partial z} + \frac{w' \partial u'}{\partial z}$$

Restating this partial differential defining equation in common words: The total change of the velocity vector component in one direction with respect to time equals the sum of fourteen terms which describe change of individual variables primarily due to our three dimensional world.

Two more such equations govern the other two dimensions. Indeed, not all such changes are possible to integrate and solve even with today's computers' ability to overcome by approximation the constraints of theoretical mathematics. But the hope of solution is Newtonian--that every turbulent eddy in the air, every ripple of waves, can be submitted to mathematical modeling. Such was Newton's hope in pure reason through mathematics.

5. NEWTON'S UNIVERSAL LAWS OF MOTION

Newton made his first law of motion that of Galileo's law of inertia.

Things at rest tend to remain at rest. Things in motion (momentum) tend to remain in motion (at equal momentum) along a straight line at a constant speed.

Rene Descartes provided a second set of shoulders for Newton to stand on. Newton used Descartes' law of conservation of momentum as his third law of motion.

For every action there is an opposite and equal reaction.

With momentum being equally and oppositely exchanged in collision, and momentum remaining unalterable unless acted upon, the essence of Newton's major contribution to all ages is his great law where he identifies that outside force causing the action.

The outside force is directly proportional to the time rate of change of motion. And the direction of that force is usually in the same direction or opposite the direction of that motion.

Again, motion must be seen as momentum. Using modern notation

$$F = \frac{d(MV)}{dt}.$$

It must be pointed out that the expansion of this equation according to the calculus is

$$F = M\frac{dV}{dt} + V\frac{dM}{dt}$$

and as such was known and understood by Newton. Many liberal arts undergraduate physics textbooks ignore the second term of this equation which deals with a moving object that can change its mass. This gives the over simplified form for force equalling only the product of mass and acceleration, F = MA. It is certainly permissible with proper concern for scope and sequence of educational methodology to feed a student only that which he or she can handle, but it is an error to teach these simplifications as the science developed by Newton, when in fact, he said so much more already in the seventeenth century. Newton's laws, already in 1687, could explain objects accelerating that were capable of accepting mass by processes of entrainment or cast off mass such as a fired projectile. With development of the calculus Newton placed physical sciences at a new

level of comprehension. Even the simplest phenomenon could not be understood without the calculus. A simple pendulum, for example, requires changing components of acceleration for the explanation of its motions, not easily reduced to algebra without the calculus. Mathematics became the language of science, and to be fluent with the laws of science, one must achieve a minimum skill of the calculus and differential equations.

Slow to publish, Newton did not receive the recognition for his priority development of the calculus, but that honor had to be shared with a German, Gottfried Wilhelm von Leibnitz, who frequently published and presented his works to both the Royal Society in London and its counterpart in Paris, the Academie Royale Des Sciences. Newton did not become a member of the Royal Society until 1671. At the Royal Society his mathematical scientific gifts were readily recognized, and he was given the strong encouragement he needed to publish. In a three volume set entitled PHILOSOPHIAE NATURALIS PRINCIPIA MATHEMATICA, published and released by the Royal Society in the years of 1686 and 1687, Newton's ideas of both a new mathematics and a new physics governing the motions of the universe were finally available to the world. Very different than Robert Boyle's work, who insisted that efficient and final causes related to the Triune God of Creation were important to the study of the natural world, notation of God at all was conspicuously absent in Newton's first edition of the PRINCIPIA.

The complete realm over which Newton's laws of motion and his new methods of mathematics, fluxions, were applied, appeared as immense as the universe itself. Newton's PRINCIPIA dealt with centripetal forces and the motion of bodies in eccentric conic sections. He provided mathematical methods for the determination of elliptic, parabolic, and hyperbolic orbits from known focal points. He provided for the determination of a similar variety of orbits when the focal points were not known. Newton calculated the changing motions in any given orbit. Detailed explanations were given for all rectilinear ascending and descending motions. Newton reworked Galileo's pendulum motions with the calculus and arrived at great sweeping generalizations that Galileo's simple empirical approach could not achieve. Not only could Newton's laws of motion, particularly the second law governing forces, determine orbits but also changing orbits and perturbations in orbits due to changing mass-distance relationships. Gravitational forces could be determined even for oddly shaped non-spherical bodies.

6. COMPLEX MOTION IN A MEDIUM WITH FRICTION

Much attention was devoted to the motion of bodies in resisting media. Given here is an example of a projectile fired straight up through a medium and then allowed to fall back through the same resisting medium. It is very complex and very detailed with precision predictions of motion at every instant. It is a triumph for Galileo's method of starting from an ideal of how things might move in a vacuum and then adding together all other forces from the intervening medium. Aristotle's explanation of a falling object through a medium was generally correct and much closer to the truth than Galileo's falling motion in a frictionless mediumless vacuum, but Newton's explanation of such realistic motion could provide detail not possible by Aristotle or Galileo.

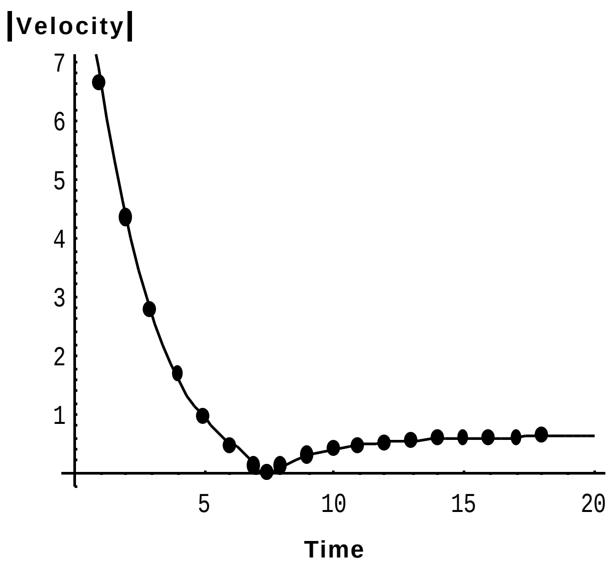
Fluxions or calculus was the reason for such success, but Newton gave the explanation in terms of geometry after he had solved the problem with calculus. (For the geometric view of Newtons solution see Newton, PRINCIPIA, University of California Press, 1934, Vol. I, page 254) One should take note of the complex problem demonstrated here. Not only is velocity changing, acceleration is also changing.

Thus, at high muzzle velocity deceleration due to gravity and friction is very high and our

projectile slows in a medium very rapidly. But as the upward velocity of the projectile continues to slow in a medium the friction against the medium becomes less and near the top of the projectile's flight the effect of friction is minimal and primarily only a constant deceleration due to gravity dominates.

Finally, at the instant the projectile comes to the top of its flight just before its decent, its velocity is shown to be zero. At this moment deceleration due to gravity becomes acceleration due to gravity as the projectile begins its free fall in a medium.

On the free fall downward descent of our projectile, gravity is causing an acceleration but the friction of the medium through which the projectile falls is simultaneously slowing the projectile. Also, as the projectile increases its velocity in the medium, the effect of the friction increases. Again we have a very complex problem where the gravity caused acceleration is a constant while the deceleration caused by friction is changing. Understand, the combination of these two effects give a changing acceleration the solution of which displays the genius of the new explanation of motion by Isaac Newton.



Accelerations are changing on the downward fall and they are changing differently then they were on the upward launch. This time, on the downward free fall the acceleration is becoming less even though acceleration due to gravity is constant. The friction from the opposing medium during the free fall is subtracting from gravity so that the net acceleration is becoming less and less. As the acceleration becomes less the falling velocity approaches a constant, a terminal velocity for a given medium.

The downward constant force of gravity is matched exactly by the growing opposing force of friction from the medium. As the forces reached this equilibrium the falling projectile cannot possibly fall faster than the velocity achieved at terminal velocity. No matter how much more the projectile has to fall before crashing into the ground its velocity will no longer increase.

7. NEWTON'S VIEW OF LIGHT

Newton also gave considerable contributions to the field of optics. We have already mentioned in chapter fifteen his invention of the reflecting telescope. He was the first to

give the modern accepted explanation of the dispersion of white light into the color spectrum. Newton passed a narrow slit of white light through a prism to produce the commonly known spectrum of colors. He then used a second prism with a narrow slit of a color and tried to turn that color into still more colors, but failed. The belief still existed from Aristotle that the longer paths taken by light through glass caused the white light to darken into red, then orange, then yellow, then green, then blue, and finally to violet. Newton, however, could not make blue light turn into any other color except blue no matter how he twisted and turned a second prism. He reasoned that the white light was a mixture of the spectrum of colors and dramatically demonstrated it by turning a second prism to take all the colors and mix them together to give white light again.

Newton insisted that light was made of particles. This was a result of his requirement for empty space. Planets never slowed down; if they did, they would eventually crash into the sun, being pulled there by ever increasing gravity as they got closer to the sun. No frictional effects were imagined in space. With a frictionless empty space, a beam of light could only move across the vast regions of the universe if it was made of a stream of particles. Most of Newton's contributions on light were presented at public forums to the Royal Society between 1671 and 1675. All of his ideas on light were collected and published by the Royal Society in 1704, the year after he became its president.

8. NEWTON'S SEPARATION OF RELIGION AND SCIENCE

Following the objectives of the Royal Society, Newton kept his religious views private. In letters to John Locke, Newton wrote "An historical account of two notable corruptions of Scriptures." Newton rejected the Trinity and was supportive of the old Arian doctrines which blamed the Christians of the early centuries for deliberately altering the Scriptures in favor of a trinity doctrine. Newton's caution against efficient and final causes for natural phenomena may have permitted him to publish. With such anti-Trinitarian views, he would not have been permitted his success at Cambridge, and in the Royal Society, he could publish freely by confining his work to mathematics and experiments using only pure reason. By 1710, Bishop Berkeley accused Newton of being supportive of atheism with his obvious abstaining from any religious reference in his scientific works. Newton, of course, was applauded by the Royal Society and to this very day, the Royal Society continues to keep religion and science separate.

Christian teachers neglecting God's work of creation and His continual control over all of nature follow Newton's lead. By teaching the laws of science as absolute and known with certainty, such teachers are doing more for the general philosophy of evolution, which holds to a natural world without God, than men like Lyell and Darwin ever did. The doctrine of uniformity, established first by Galileo, believed, but not formulated by the ancient Greeks, and firmly established in every branch of science by Newton with his universal laws, gives the people of the next centuries a godless world that they will be willing to accept.

Denying God his role as creator and maintainer of the natural world is atheism. In 1713, at the encouragement of the editor of the second edition of PRINCIPIA, Roger Cotes, the "General Scholium" was added in which Newton declared the existence of God. The Christian knows there is much more to the natural world than only that which can be comprehended by reason alone. Reason alone keeps science separate from His Word.

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SEPARATE FROM HIS WORD

CREATION LOST: Atoms Return, Chapter 18

The Royal Society provided a forum for all major branches of science where experiments could be performed and arguments presented, all in the hopes of convincing the members of a certain viewpoint of nature. This society was dedicated to the improvement of natural knowledge by experiment. Its members argued their ideas through strict mathematical demonstrations and reason alone. France was the first nation to copy the idea from Great Britain. Soon nearly every nation of Europe developed such a society while the Royal Society branched out into many professional societies dedicated to a specialized discipline. These groups all had several things in common. They all were dedicated to the expansion of knowledge through experimentation. They tried to keep harmony among their membership by granting freedom from religion. Such freedom was practiced by not giving reference to religion at all, or at best, giving only a superficial reference to a divine being of providence. International exchanges between these societies were common even during major wars. All these scientific societies became involved with publishing books, providing lectures, and establishing journals. This practice caused an explosion of information and created the professional scientist of our modern age.

These societies also formed editorial boards which were not designed to serve as censors and were usually made up of very open-minded persons, but inevitably they would define the important problems and the methodology of pursuing the answers. Science, in this manner, could surge ahead by not being required to repeat many discoveries and arguments over and over again. For this advancement a price of hidden censorship was extracted. As an example, Robert Boyle's experiments with a vacuum chamber could not find aether. Not finding something is a long way from being certain that such a thing does not exist. Isaac Newton's concept of universal gravitation among the stars and planets required space throughout the universe to be a void. Again, just because one's theory only works if there is no aether does not mean, in fact, that there is no aether. However, with Robert Boyle being a founder and Isaac Newton being president of such a prestigious society of the top scientists in the country with high reputations throughout the world, a scientist with different ideas about aether had difficulty expressing his views in the accepted scientific literature.

On the positive side, it took the full prestige of the Royal Society to overcome the entrenched beliefs of Empedocles on the elements or the science of Aristotle. After Robert Boyle maintained the respect of the Royal Society with regard to his skeptical view of the existence of fire as an element, only then could other scientists in the world of alchemy move toward different explanations of matter.

1. KNOWN LAWS OF PHLOGISTON

In the eighteenth century, a substance called phlogiston was identified as the "food of fire" or the "inflammable principle." It was believed that all substances contained phlogiston. Substances that burned contained large quantities of phlogiston and readily released them. A burning candle, for example, released phlogiston into the air. When a candle with a flame was covered up by a large container, the flame soon went out because the air under the container became saturated with phlogiston and could not accept anymore. As soon as the container was lifted, more phlogiston was able to come out of

the candle and the flame could be ignited again.

Phlogiston did not support life. It was a residual gas that came out of food "burned" in the digestive track of a living creature and exhaled. Thus, the chief purpose for breathing was to remove excess phlogiston from the body. Air then became impure when it contained a high percentage of phlogiston. Coal gas from mines was high in phlogiston content. In 1772, Joseph Priestly, a British chemist and a non-conformist minister, out of interest in measuring the purity of air, developed a standard chemical test to determine the quantity of phlogiston in a given sample of air. The standard test required a chemist to take two volumes of the air to be tested and mix them with one volume of nitrous air. It was common to collect gases in jars by the displacement of water, and that same procedure became part of the standard test. As a result, when the sample of air was mixed with nitrous air, a chemical reaction occurred forming red fumes which cleared away as they became dissolved in the water. If pure air was used in the original sample, a residual of 1.8 volumes of gas remained. If a fully phlogisticated sample of air was tested by Priestly's standard test, no reaction would occur and a full 3.0 volumes of gas remained. It became a very useful test and can be credited with saving the lives of many coal miners who worked long hours in air with varying quantities of phlogiston.

Another important property of the chemistry of phlogiston was related to metals. It is important to realize that earth was identified as an element. Ores of metals were seen as elements and of a simpler form than the metals themselves. If an ore was heated and burned with charcoal, a source of phlogiston, the chemical reaction between elements of earth and fire, metallic ore and phlogiston, produced a compound called metal. Specifically, hematite burned with charcoal produced iron. Iron was a compound made of an earth and phlogiston.

2. KNOWN LAWS OF CALORIC FLUID

During the mid eighteenth century, Joseph Black made a sharp distinction between temperature and heat and developed an equation still in use today, $dQ = SM(dT)$, in which dQ is the quantity of heat added or given off by a substance with a mass M which experienced a corresponding temperature change of dT. An empirical constant needed to permit the equation to work, S, the specific heat given in calories per gram per Celsius degree, was different for every substance and showed how some substances had a greater heat capacity than other substances.

Joseph Black taught that heat was an elastic substance called caloric fluid which repelled itself but was attracted to all other substances. When the particles of a substance were surrounded by caloric fluid, which entered between the particles of the substance by the attractive forces, the particles would spread apart according to the repelling forces. In this way caloric fluid gave the best explanation for expansion. Because heat was a substance, it was expected to have weight, although such weight escaped detection at first. Also, caloric fluid, being a substance, obeyed the time-honored law of conservation of matter. Heat could not be created or destroyed, but it could be passed from one substance to another. The heat lost by one object was gained by another. This, then, was the first law of thermodynamics.

Different kinds of heat were identified. The most common was sensible heat in which the senses could feel the change of heat through temperature changes. Latent heats or hidden heats formed a larger category. Two hidden heats survive to this day. The heat of fusion was the hidden heat that came out of water when it chemically turned into the substance ice. The temperature would drop as the water was cooled until it reached 0

degrees C. This was sensible heat leaving the water. In the freezing process, the temperature did not change, but remained at 0 degrees C until all the water was frozen. The heat departing was a latent heat and for water at 0 degrees C was 80 calories/gram. A similar hidden heat, the heat of vaporization equal to 540 calories/gram at 100 degrees C, had to be added to water in order to turn it into steam before the temperature of the steam could rise any higher.

Other latent heats were identified. The heats coming from chemical reactions were hidden forms of caloric fluid. Differences between heats involving phase changes and chemical changes were not recognized. Instead, steam was seen as a compound made of water and caloric fluid. Heats of fracture, heat generated by bending and breaking metals, were also hidden forms of heat.

The sciences dealing with phlogiston and caloric fluid gave effective new results, although they were built on older concepts of elements. James Watt, a contemporary to Priestly and Black, built his first steam engine maximizing the awesome quantities of heat exchanged in the chemical reaction of water and caloric fluid. His engine, that was improved by 1784 as a double-acting rotative engine, created the modern factory with machines, led to steam locomotives, and finally steamships that could cruise the ocean without the need for a sail.

3. TROUBLE WITH FIRE

With the publishing of John Dalton's A NEW SYSTEM OF CHEMICAL PHILOSOPHY in 1808, all relationships to the four elements of Empedocles were effectively eliminated. Questions about the "food of fire," phlogiston, were first raised in 1772 when Antoine Laurent Lavoisier noted that both sulfur and phosphorus burned by themselves without charcoal or some other source of phlogiston. He found that both sulfur and phosphorus gained weight while burning. By digging into past recorded data of others, as well as making new observations, the puzzle of weight for phlogiston grew. It was consistently noticed that when a metal as a compound was allowed to decompose, such as iron allowed to rust, the residual material called calx always weighed more than the metal. According to the accepted phlogiston view of matter, this process was the reverse of forming a metal. The metal would decompose releasing phlogiston and become closer and closer by calcification to forming an earth element. As an elemental substance, the calx should have weighed less. Inconsistencies rarely cause science to abandon its well-accepted laws, although the inconsistency of more weight for a calx, an element, and less weight for its metal, a compound, was, indeed, a puzzle not easily reckoned with. Negative weight for phlogiston was considered. Lighter-than-air gases existed; something similar might be true for phlogiston.

Quite apart from the weight problem, an orange powder which was the source of mercury gave an interesting chemical reaction that attracted a lot of attention. By heating the orange powder, mercury could be obtained; but also by heating the mercury, the orange powder returned. In the process of accumulating the mercury, a strange gas could be collected. Joseph Priestly applied his standard test for the purity of air and measured 1.6 volumes of residual gas, a numerical value signifying a gas purer than elemental air, which was impossible. A measured value just 0.2 from an expected value is not much, certainly not a significant amount to make a valid judgment when considering limitations of the measuring devises. However, because the very essence of chemistry with its four chief elements, particularly elemental air, was presenting seemingly wrong results during standard procedures, scientists resorted to very non-standard procedures. Priestly, in 1775, took the residual gas after it was tested and successively kept testing it. He ended

up each time with less gas until there was no residual gas at all. Priestly was holding a new element in his flask, but instead called it dephlogisticated air. To him it was a form of the ordinary air which, in the chemical process, was made purer than it normally could be. He understood this as super saturated solutions of today are understood, that hold more solute than they normally could hold.

Lavoisier, in communication with Priestly, repeated the experiments and found the same results. Lavoisier also found that this strange gas supported life and, in fact, after this strange gas was tested for purity, it still supported life. It was a known fact that the residual gas, after the standard test for purity, would be fully phlogisticated in the test. When a mouse was still capable of living in the residual gas, even after supposedly all of the good air was used up, it meant to Lavoisier that this gas had to be a new element. This previously unknown gas became known as oxygen.

By this single stroke of bold interpretation, Lavoisier identified a new element when new elements were not supposed to be found, and all four of Empedocles' elements collapsed. An ore, formerly an element of earth, became a compound of a metallic oxide. The metal, formerly a compound of earth and fire, became a metallic element. The candle, when it burned, did not give off phlogiston. The flame was supported by the intrusion of oxygen. The flame of the candle went out when it was covered up because the candle was denied oxygen. A candle in an enclosed container burned the oxygen causing a partial vacuum which allowed water to enter the container, leaving less volume above the water than before, not by the compaction of air and phlogiston, but by the loss of oxygen as a free gas. An animal breathed in oxygen which was used in the chemical processes of the body and breathed out carbon dioxide. The "food of fire," phlogiston, disappeared as an element. Oxygen became one of many elements that made up the air. And, finally, Lavoisier interpreted Henry Cavendish's results to show that water was a compound. The elements making water became known as hydrogen and oxygen. The death of the four elements should have been complete with Lavoisier's 1783 publication of REFLECTIONS ON PHLOGISTON.

This sweeping revolution in chemistry was not readily accepted. Other changing views of science delayed the chemical revolution for many. Both the release of the hidden heat of vaporization (540 calories/gram) in condensation and the expansion of water to a volume of more than a thousand times greater as steam gave power never seen before. But with these great quantities of heat and energy, it was still believed that metals in contact with hot steam under high pressure readily decomposed into calx. Steam plus metal gave calx plus phlogiston. Henry Cavendish saw water as a result of combining dephlogisticated air and phlogiston and was reluctant to abandon phlogiston.

Such caution kept the concept of phlogiston alive for nearly a half century, and it was not disclaimed until it could be convincingly demonstrated that water was made of other elements. This was not easy since ice, water, and steam were viewed as separate substances. Also, confusion over the atomic weights of elements in the new atomic theory developing in these same years did not permit clear convincing methods for separating the elements. These atomic weights were not easily determined without circular reasoning. Only when technology developed to the point where hydrogen gas and oxygen gas could be placed in a glass tube and ignited by an electrical spark to give water vapor which could be condensed for an exact weighing could the formula H two O be determined. Then water as an element could be rejected, and that did not occur until just before the twentieth century.

The caution displayed by Cavendish did not inhibit Lavoisier, and in 1789, he published TRAITE ELEMENTAIRE DE CHEMIE which changed all the fundamental definitions of

compounds and elements and provided the laboratory methods for careful determination of weights of substances before and after chemical changes. It was obvious to Lavoisier that a calx took on oxygen and was supposed to weigh more than the metal. The difference of the weights between the calx and the metal had to be the weight of oxygen.

Lavoisier enjoyed the established royalty. His father purchased a title of nobility for him, and Lavoisier became secretary and treasurer of a special commission which in 1790 established uniform weights and measurements for all of France and its colonies. Today these are the units of measurement of the metric system. But Lavoisier's love for the nobility and his work with the government's treasury identified him with the wrong side in the French revolution. Lavoisier was executed with the guillotine at the age of fifty in 1794, and his severed body was thrown into a common grave.

4. HEAT WITHOUT LIMIT

Much scientific effort was spent pursuing the weight of caloric fluid. Like phlogiston, caloric fluid was imagined as a very subtle substance so extremes were sought to measure its weight. The extreme of freezing released 80 calories of heat for every gram of water. George Fordyce, in 1785, consistently measured ice and found it to weigh a very small fraction heavier than water (1 part to 129,000 parts). Again, like phlogiston, caloric fluid showed a negative weight since ice plus caloric fluid gave water. Some people with modern views might judge negative weight as a condemning measurement showing the weakness of the theory. However, it was no more a weakness in 1785 than it is a weakness to talk about matter and anti matter in the twentieth century.

Benjamin Thompson (1753-1814), an American born scientist was rescued by royal troops in the British evacuation of Boston in 1776. In England he was elected to be a fellow of the Royal Society and spent much of his scientific study on explosives and the construction of fire arms. He was knighted by King George III, served the British Empire as Minister of War, and became a special military ambassador of England to Bavaria. He gave advice to Bavaria about weapons and explosives in their struggle against the Turks as well as learning from Bavaria the construction of massive field cannons used on the mainland of Europe, knowledge most useful to Britain. If such cannons could be converted to shipboard use, it would enhance the growing naval power of Britain.

While working with such cannons in Munich, Benjamin Thompson (Count Rumford) performed studies on the substance of caloric fluid. He compared flasks of alcohol and water of exactly the same weight and permitted them to cool below the freezing point of water until all the water was frozen and discovered, like George Fordyce, that ice weighed more than the water from which it was frozen. In communications with Benjamin Franklin, Benjamin Thompson learned that heat capacity might be quite different than heat conductivity. Thompson reworked his experiment allowing for extremely long periods of time for cooling and eliminated the chance of outside condensation on the sealed flask of ice. He found that his flask of alcohol and flask of ice weighed the identical amount. Benjamin Thompson, in spite of war all around, showed the need for international exchange of ideas which were beneficial to the growth of science. Being familiar with Lavoisier's (French) work on phlogiston and taking Franklin's (American) direction, Thompson (British) in Munich could conclude caloric fluid had no weight.

Continuing his munitions work, Thompson performed several heat experiments with cannons, In the key experiment which changed the world view of heat, Benjamin Thompson deliberately used a dull drill which could not drill out any more of the barrel of the cannon. He enclosed the section of the cannon against which the dull drill was

applied with a water filled wooden case and generated heat without limit bringing 60 degrees F water to boil every two and a half hours. The production of heat without limit indicated that heat could not be a substance. Caloric fluid as a substance could not exist. Heat via friction had to be in some way related to motion. This great revolutionary idea was presented to the Royal Society in 1798 in a paper entitled "An Inquiry Concerning the Source of the Heat which is Excited by Friction."

Like the science of phlogiston, the established scientific views of caloric fluid did not die overnight, even though the demonstration experiments were thorough and convincing. Steam power appeared to provide incredible quantities of heat, and steam was viewed as a substance chemically different than water. Until phase changes could be seen as common to all substances and be interpreted as a result of molecular motion, caloric fluid did not disappear. In fact, another law of thermodynamics was built on beliefs in the existence of caloric fluid. As late as 1824, Sadi Carnot, a Frenchman, published REFLEXIONS ON THE MOTIVE POWER OF FIRE. Carnot was troubled with the seemingly large quantities of heat produced by steam engines which could not be converted to other useful forms of heat. The loss of heat was a great discrepancy in the first law of thermodynamics which said the substance of caloric fluid could never be destroyed. Carnot's solution was to describe some heat in every heat exchange process as being transformed into entropy, a non-useful form of heat which was not destroyed, but which was in essence lost from effective use. Even James Prescott Joule's great work in 1847, "On the Calorific Effects of Magneto-Electricity and on the Mechanical Value of Heat," only referred to mechanical equivalence of heat. The demonstration showing convincingly that heat was a form of energy from molecular motion would not come until Albert Einstein's mathematical work in 1905 on the motion of suspended particles in which he related heat and temperature to exact statistical ranges of motions of molecules. Einstein showed that the molecular kinetic energy was identical to the thermal energy which is heat as it is defined today.

5. JOHN DALTON'S ATOMS

At the start of the nineteenth century, fundamental beliefs about earth, fire, air, water, and aether as elements were collapsing. With the ancient view of continuous matter in various stages of rejection, another ancient idea for matter was turned to. John Dalton, in 1808, published A NEW SYSTEM OF CHEMICAL PHILOSOPHY in which he called for all chemical analysis to be done with a world view that saw all things made of indestructible atoms with empty space between them. These atoms were quite similar to the atoms of Democritus. If all of the changes made in the eighteenth century would have been fully accepted by all scientists, atomic theory would have been blown into acceptance like a sudden storm. Newton needed empty space for his planets moving in a frictionless solar system, and he also needed tiny particles for the propagation of light. With phlogiston gone, and air and earth being made of many elements, new particles were needed to carry the new elemental properties. Lavoisier led the way by showing weight gains and losses were due to the addition and loss of colorless transparent oxygen. Benjamin Thompson's cannon experiments showed a need for a source of unseen moving particles.

Dalton's atoms were different from those of the ancient Greeks because his description of atoms provided methods to test for the existence of them. From the start, John Dalton claimed atoms were "knowable" to scientific investigation. The single most important property of an atom was its weight. Such fixed bundles of weight could be tested by knowing how elemental atoms combined into molecules and formed the compounds according to fixed whole number ratios. "Rules of simplicity" governed how atoms

combined into molecules to give the compounds. When one and only one compound made of two elements was known, Dalton's "rules of simplicity" claimed that compound was a "binary" meaning each molecule had one atom for each of the two elements involved. NH for ammonia, HO for water, and CaO for calcium oxide were some examples. When two different compounds made of the same two elements existed, one compound was a binary and the second one was a ternary. CO and CO two were examples of binary and ternary compounds. Dalton used picture symbols (FIGURE 18.1) as we use letters which provided for excellent conceptualization for moving unseen atoms around.

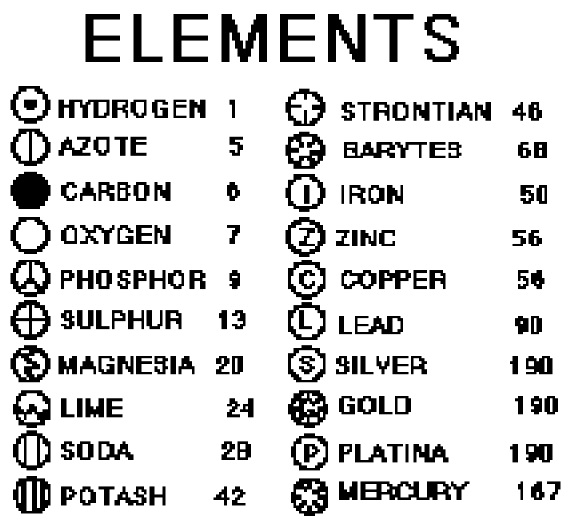

FIGURE 18.1 SOME OF DALTON'S ATOMIC SYMBOLS

NH and HO displayed immediate problems which exposed errors in the rules of simplicity. Believing all atoms will combine in whole number ratios to make molecules, a person must have the chemical formula to find the weight ratios of the atoms. Knowing water was HO and measuring 85+(2/13)% of water as oxygen and 14+(1/13)% as hydrogen, Dalton determined a mass ratio of one to six between hydrogen and oxygen. Other formulas and other combinations of elements giving different compounds led to the beginning of a long list of atomic weights relative to hydrogen. Chemical formulas, however, were not known apart from Dalton's invented rules of simplicity. Working from atomic mass ratios sometimes gave different chemical formulas. Essentially the chemist needed to know the chemical formula to calculate the atomic mass ratio and he or she also needed to know the atomic mass ratio to calculate the chemical formula.

When facing the unknown, circular reasoning always follows the scientist. Newton needed the mass of the earth to determine the force of gravity or the gravitational constant, but he needed to know the gravitational constant to calculate the mass of the earth. Circles of reason, flaws of logic, are unavoidable and are generally overcome by repeatedly going around the circle often enough until one becomes convinced. The dizzying ride does not eliminate error.

Atomic chemistry was also plagued with elemental substances that had multiple atoms per molecule. O two, O three, N two, F two, S two, S six, and S eight are some common allotropic forms of elements. Also many compounds of the same set of elements, such as FeO, Fe two O three, and Fe three O four, not following the rules of simplicity, added to the confusion. Amedeo Avogadro, in 1811, reasoned that in a gaseous state in a given volume, an exact number of molecules existed. Once this was confirmed a century later in 1908, finally an independent method, apart from the formula-mass circle of reason, could be used to determine atomic mass ratios and more certain chemical formulas. Some polyatomic elemental molecules could be identified. For the full nineteenth century, chemists hammered the data in their mortars with uncertain and confused results. Only after Einstein's mathematical demonstration of atomic motion in 1905 and its application used in determining Avogadro's number of molecules (602,000,000,000,000,000,000,000) in a given volume of gas (22.4 litres at 273 K and

1.00 atmospheres) were the presence of atoms confirmed for the twentieth century.

Dalton's atoms were a great success, but not because of observational evidence. Dalton himself had collected over 200,000 detailed weather data over fifty-seven years which for science were useless. Likewise observational data of chemistry were simply too confusing to provide sensible meaning. Dalton's atoms were a great success because they gave a model around which to interpret a large confused set of chemical data, and at the same time provide testability. Indeed, the tests gave many failures along with some successes. The beauty of science is that its failures can be rehammered. Sometimes the hammering forces the data into the proper mold and sometimes the hammering changes the mold. Without the mold, the data remain useless.

Scientific societies were especially effective in keeping science as science only, without conflicting views of philosophy or religion. Science grew rapidly. It is not surprising in such loyal scientific societies, which were dedicated to explanations of nature without God, that the Greek atomic science which eliminated gods completely, came back to prominence. Ideas like eternal atoms without beginning or end and moving atoms which caused changes in materials by themselves, uncaused without divine guidance or intervention, returned. Oddly enough, old questions raised by Plato about the uniqueness of the mind over against an assemblage of atoms no longer were asked. Perhaps the ancient ideas of continuous matter were too wrong for too long to allow these questions to be raised.

Benjamin Franklin mapped the Gulf Stream, a major current in the Atlantic Ocean, confirming one more error of Aristotelian science. Franklin's explanation of electricity as a fluid with a plus charge for material with an excess of electricity and a negative charge for a lack of electrical fluid became a stumbling block to atomic chemistry. Electricity provided a finer grain than the whole atoms and escaped from being interpreted as particles for another century. Thus the new science of electricity slowed the acceptance of a particle structure for matter. Wave theory of light confirmed by Thomas Young's (1773-1829) famous demonstration of light interference patterns further eliminated empty space, restored aether, and challenged the entire atomic theory as a realistic view of nature. The next age would struggle over the religious and philosophical meaning of the rapidly changing views of nature in science set free from such constraints. Creation as a guiding principle was lost. Scientists interpreted nature as operating by itself.

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SEPARATE FROM HIS WORD

THE INVENTION OF UNWRITTEN HISTORY: Leclerc to Darwin, Chapter 19

1. CLOSING ARISTOTLE'S GAPS

In 1630, when Galileo Galilei wrote the DIALOGUE ON THE TWO CHIEF SYSTEMS OF THE WORLD, he expressed the view that corresponding causes everywhere produced corresponding effects and destroyed the Aristotelian gaps that treated the celestial world differently from the terrestrial world and biological science differently from physical science. The laws of science, according to Galileo, governed all materials, living or non-living, the same way in all parts of the universe. Newton's laws of motion confirmed this doctrine of uniformity by showing dramatically that even the stars obeyed the universal law of gravity.

This material and mechanical view of nature, avoiding efficient and final causes and promoting only rational explanations supported by experimentation, gave interpretations for every aspect of nature. A gravity interpretation for simple pendulum motion was expanded to explain the shape of the globe and to give a rationale for deviations apart from a perfect sphere. Gravitational explanations provided reasonable causes for ocean tides and currents. Volcanoes and earthquakes were seen to respond to gravitational forces. Stratified rock formations were explained by sediments gravitationally settling in water. Finally, all land formations were explained in part by balanced gravitational, frictional, and pressure-produced forces. Mechanical interpretations even provided explanations for animal and plant growth and their respective functions.

2. NIELS STENO'S EXPLANATION OF FOSSILS

Niels Steno (1648-1686) gave the first widely accepted explanation of fossils, previously a puzzle for many centuries. He accepted as fact that fossils were once living creatures. Plain reason was used to develop the rest of the explanation. Niels Steno argued that when a living creature died, its body was rapidly entombed by sediments settling gravitationally in water. A cementing process turned sediments into rock, and the slow moving minerals in the porous surrounding rocks gradually replaced the dead body, giving an exact replica of the dead creature in crystalline stone. Steno also produced considerable work on live dissections of animals applying principles of physics that Galileo initiated. Steno showed, for example, that the physical volume of muscles did not change as they flexed and moved from a relaxed state to a state of tension. He showed that the strength of muscles was not dependent on a spirit of life by demonstrating that the legs and tail of a tortoise could continue to exert a force even twenty-four hours after its head was cut off; a frog could still swim after its heart was removed; and the heart could continue to beat separate from the body from which it was taken. He concluded muscles flexed by mere stimulation of nerves.

3. CLASSIFYING GOD'S CREATURES

With applications of principles of physics to biological creatures achieving considerable success, there was much pressure to systematize the biological world. Carl Linnaeus

(1707-1778), a Swedish biologist, set out to name all creatures, and in the process gave us the modern biological classification system for living creatures using a binary nomenclature. In his life's work, it is difficult to pinpoint an article or a book that presents Linnaeus' system straightforward and complete, but two books, SYSTEMA NATURAE published in 1735 and SPECIES PLANTARUM published in 1753, provide the structure of his system. Carl Linnaeus followed Aristotle's method for developing a classification system presented in the ancient work HISTORIA ANIMALIUM. Aristotle had arranged biological creatures in a "ladder of nature" ascending a scale of perfection guided by the potential of the living creature. His arrangement showed a hierarchy according to reproduction. On top of Aristotle's ladder were creatures whose young were born fully formed; lower were birds with perfect eggs; and still lower, were fish with imperfect eggs.

Carl Linnaeus built his classification system similarly on minute differences of reproduction and then visible body parts. His most original work was done in botany where his descriptive work of each plant needed for classification and naming vividly described sexual interplay of the plants. He divided plants into twenty-four classes according to the number of and characteristics shown by plant stamens. In his sexual descriptions, Linnaeus used terms like "bridal bed provided by petals" and identified plant movements in human terms such as "pure marriages," "promiscuous living," and "adultery." In his society such descriptions appeared risque and met some rejection. As a result, a large cadre of loyal followers smuggled specimens to him from all parts of Europe and occasionally from other parts of the distant New World. As wars developed between France, England, and Holland, many specimen collections were smuggled across the Swedish borders and run across naval blockades at considerable risk.

Linnaeus started with a broad grouping called class. Listed as classes were mammals, reptiles, fish, insects, and vermes. As an example, Linnaeus used the technical term "aves" for birds. Order was the next narrowing group. "Procellarii formes" was that order of birds which had tubular nostrils and came to shore only for very brief periods of time to breed and nest, while the remainder of their lives was spent at sea. Genera was Linnaeus' next narrowing group. "Diomedea" would be the genera which identifies albatrosses, primarily southern hemisphere birds with very long wing spans. The narrowest group in Linnaeus' system was the species. In this example, let us pick "exulans," the species of the wandering albatross, the largest breed of albatross which has twelve foot wing spans and can continue to fly in gale winds. Linnaeus' name for the wandering albatross would be "diomedea exulans" taking the names of the genera and species. This then would be the complete keying of a bird to a distinction where no more separating could be made other than for minor varieties. The minor varieties were ignored since interbreeding among the varieties occurred. Carl Linnaeus adamantly insisted that no new species existed that was not created during the six days of creation recorded in Genesis. Linnaeus claimed that the species were unalterable and never changed. Acceptance of this constancy permitted the rapid growth of scientific knowledge by taxonomists all over the world. Exacting classification systems finally could place all of botany and zoology under systematic scrutiny, allowing a physical mechanical explanation for life.

4. A NEW HISTORY

George Leclerc, Comte de Buffon (1707-1788), a French naturalist, developed forty-four volumes of natural history that were published during the years 1745-1804. These volumes displayed a complete interdisciplinary study of all of nature ranging from detailed studies of birds, reptiles, fishes, and cetaceans to the chemistry of minerals. As a scholar of Newton's fluxions, Leclerc published explanations of the new mathematics in French and applied it to both the biological and physical world. His mathematical interpretations of

these two worlds led to his development of the first comprehensive natural history of the earth. Leclerc's computed age of the earth far exceeded the time allotted by Bishop Ussher between the creation and the present.

Leclerc built his natural history on the knowledge that the earth was an oblate spheroid. He noted that very little heat was received by the earth from the sun when compared to the immense heat within the earth as witnessed by the molten rock spewed from the inner earth in volcanoes. Leclerc saw the mountains being altered by volcanoes and also judged earthquakes as part of the volcanic process. He viewed the movements of mountains as a result of the motion of molten magma beneath the mountains. The distribution of plant and animal life and also the distribution of fossils completed the historical picture developed by Leclerc and published in 1778 titled EPOQUES DE LA NATURE.

The natural history in this work developed by Leclerc was outlined in seven major epochs. The first epoch described an earth incandescent, in flames, and everywhere molten, formed by a collision of a comet and the sun. The earth's spheroid shape took form as the molten mass was cooled, a process calculated by using the most up-to-date knowledge of thermodynamics and accounting for changing variables with the newly developed calculus. All steps were logical and proper within the realm of science. Leclerc calculated time for such cooling to be about 3,000 years.

The second epoch was seen as a slower, gradual consolidation of the earth's crust, leaving the interior of the planet still molten. Rents in the earth's crust were frequent, large, and violent as the solid crust would trap immense quantities of heat and gases to be released in volcanic eruptions. Many of the metallic ores within the mountainous rocks of today were formed during this second epoch according to Leclerc. Gradually some stability was developed as the cooling of the earth continued with the mountain ranges becoming well developed, still showing where most of the former renting and faulting in the crust had occurred in the past. This epoch was computed to have lasted about 35,000 years.

The third epoch lasted about 20,000 years. During that time, cooling of the earth continued. The crust of the earth became fixed, keeping heat in the interior of the planet. Atmospheric vapors condensed to form the oceans. Life began as simple forms in the ocean. However, with a hardened crust, the earth's fourth epoch was short as excess heat punched through with frequent violent volcanoes for some 5,000 years, the duration of this epoch.

Finally in the fifth epoch, the earth became a calm planet, permitting life to develop first at the poles where the earth was cool enough to support life. As the earth continued to cool and the sea and the continents remained calm with respect to volcanic and earthquake activity, life migrated toward the equator from both poles. During the sixth epoch, some land masses broke up again and separated. It was during this epoch that man was thought to have appeared. During the seventh epoch, the epoch of the present, mankind exerted his supremacy over all the earth and its creatures. The earth continued to cool. Earthquakes and volcanic activity occasionally acted up violently, but over time, would continue to diminish as the planet continued to cool. Eventually, since Leclerc saw most of the heat of the earth coming from within the earth and not from the sun, the earth would become a cold dead planet as the cold polar regions would continue to grow. Continental glaciers would push all creatures into extinction. The overall age of the earth, according to Leclerc, came to about 100,000 years.

Although many detailed changes have been made and geological eras have new names

and more detailed events associated with them today, the overall scheme of a planet cooling into its present state and the evolution of life responding to the cooling changes of that planet still follows this general outline of natural history developed by George Leclerc. The great national exploring expeditions of England, France, Germany, and the United States confirmed two very distinct types of life in the opposite polar regions migrating equatorward. As late as the global study conducted by many nations during the International Geophysical Year (1957-1958), Antarctic ocean waters were confirmed to be the richest life-bearing waters spreading equatorward. The picture of migration interpreted by these exploring expeditions with the lead given by Leclerc did not follow a simple outward migration from the mountains of Ararat as some church leaders might have described. Just how a Noahic flood fit into the New World and the seemingly infinite variety and complex distribution of life were not solved by the new generation of scientists committed to the principle of reason alone supported only by experimental evidence.

A world view such as the natural history of the earth by George Leclerc, stretching backward in time much farther than documented history, created the new multidisciplinary science of geology. James Hutton (1728-1797) from Scotland tried to trace the natural history of the earth back through witnessable changes in the minerals of the rocks. For example, he noticed many newer rocks were formed out of worn down eroded parts of older rocks. Many minerals within rocks were laid down as sediments and pressed together from the tremendous pressure of both sea and magma from under the earth's crust. Pressure and heat were seen as the forces transforming sedimentary and igneous rocks into rocks of different crystalline structure with different mineral characteristics. Using the known laws of physical chemistry and expanding Galileo and Newton's principle of uniformity to time, the neglected fourth dimension, Hutton constructed the past on the basis of what he saw happening in nature in his lifetime.

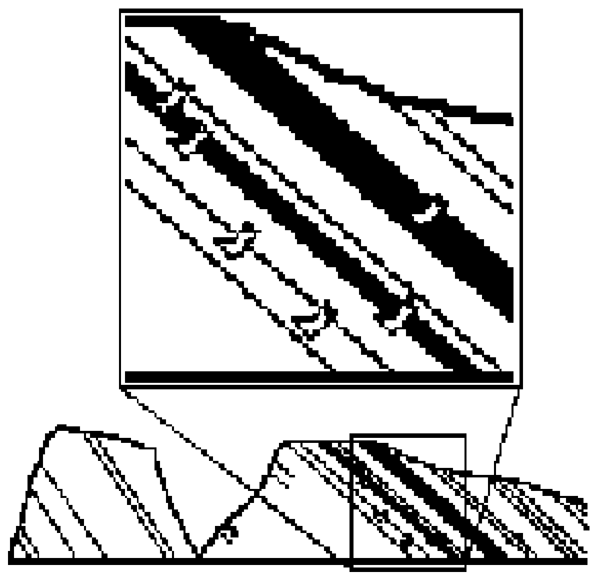

FIGURE 19.1 A SKETCH OF SIR CHARLES LYELL'S ANALYSIS OF THE GEOLOGY OF CLIFFS IN NOVA SCOTIA. THE MANY STRATIFIED LAYERS REPRESENTED MANY ADVANCES OF THE OCEAN. TO LYELL, AS TO HUTTON, THE PRESERVED FOSSIL TREE STUMPS SHOWED THE VARIOUS ANCIENT SOIL BEDS OF DIFFERENT FORESTS BETWEEN THE ERAS WHEN OCEAN SEDIMENTS COVERED THEM. (Charles Lyell, TRAVELS IN NORTH AMERICA, Vol. II, New York: Wiley and Putnam, 1845, page 151.

When viewing the many stratified rock layers, Hutton observed many erosional features along the surfaces between the layers. He also recognized rock fragments from a lower layer were embedded into the layer immediately above it,

indicating slow gradual erosional changes. Even the major stratified layers of rocks revealed many sublayers. James Hutton's new natural history of the earth rejected a single global flood in preference for many local although still widespread floods. These many floods or ocean advances formed the many layers with much time between floods to account for the erosional features. Illustrating Hutton's views Sir Charles Lyell, a geologist of the next generation, established the techniques for drawing diagrams which highlighted the many stratified layers (FIGURE 19.1, A sketch of Lyell's Fig. 18, from TRAVELS IN NORTH AMERICA, Vol. II, New york: Wiley and Putnam, 1845, page 151). (The formation of polystrate tree fossils recorded in Lyell's diagram have been explained as a result of a catastrophic flood by Rehwinkle, p. 195, and Ackerman, p. 84, and not due to long time slow processes.) The views of Hutton were made public in a paper written in 1785 titled "Theory of the Earth, or an Investigation of the Laws Observable in the Composition, Dissolution, and Restoration of Land upon the Globe." The age of the hundred thousand year old earth of Leclerc had to be expanded into a million or more years to account for the many oceans which covered a land mass and receded in one age and then in another age covered the land and receded once more.

5. NEW DISCOVERIES AT SEA

Since the discovery of the New World and the realization that Ptolemy's ancient map of the world was quite wrong, the sea-going powers of the world struggled to colonize the new lands and dominate the shipping lanes important for trade and material exploitation. Fierce rivalries developed between England, France, and Holland. The English drove the French out of North America and India, and in the English struggle to dominate the sea, they sent out exploring expeditions to all parts of the world in order to understand the sea better, to find new lands, and accurately chart what was known.

One of the first such major expeditions was that led by Capt. James Cook. His first voyage lasted from 1768 to 1771 using only one ship, the H.M.S. ENDEAVOUR, with ninety four men. He took along Joseph Banks as a naturalist, Dr. Carl Solander as a botanist, and Charles Green as an astronomer. Capt. Cook was assigned four specific objectives by His Majesty King George. The first was to observe and take careful measurement of a transit of Venus, the passage of Venus between the sun and the earth, which was predicted to occur on June 3, 1769 and was visible only from the Pacific Ocean. The Royal Society was especially interested in this since planetary motion still remained a mystery. No one had been able to observe heliocentric parallax, a phenomenon Aristotle insisted had to exist if the earth moved. The use of Newton's better telescope had failed to demonstrate the elusive motion of near-by stars moving opposite the believed motion of the earth. The transit of Venus would not show such heliocentric motion either, but by studying details and triangulation, it was hoped they might give new insights and new proofs for earth motions.

A second scientific objective was proposed by Alexander Dalrymple, a British hydrographer working for the East India Company. Still studying the geography of Ptolemy, Dalrymple strongly believed that a south polar continent existed. He believed that the land now known as the North Island of New Zealand discovered by Tasman was a northwardly protruding peninsula of Antarctica and would hopefully be a rich inhabitable continent still undiscovered. (Review Ptolemy's map, FIGURE 11.3) The British admiralty honored Dalrymple's request that exploration be done, but limited Capt. Cook to sailing no further south than 50 degrees South Latitude. As a third objective, Capt. Cook was to chart exact positions of known islands for the Crown using new and better chronometers (clocks with multiple pendulums that marked time evenly on a rolling and pitching ship). Finally, Capt. Cook was to claim for Britain any new islands before the French might find

them.

Capt. Cook sailed south from England around Cape Horn through the Drake Passage to Tahiti where the astronomical observations of the transit of Venus were made. He discovered the Society Islands, mapped the complete coast of New Zealand, discovered that the North Island was separate from the South Island, and that neither island was connected to the sought after southern continent of Antarctica. Capt. Cook made the first landing on New Zealand and discovered the Maoris, cannibals. Continuing westward, Capt. Cook discovered the Great Barrier Reef off the coast of Australia and found a passage through the East Indies between Australia and New Guinea.

During the entire voyage, specimens of rocks, plants, and animals were taken. The men of this expedition were the first to see crocodiles, flying foxes, dingoes, wallabies, and kangaroos. Capt. Cook and his scientists brought back to England 1,500 specimens and drawings of trees, flowers, birds, insects, and other land and sea creatures never seen before in all of Europe. In one port so many different forms of plant life existed that it was named Botany Bay as a special preserve for science. (This bay eventually became the infamous chief port of entry for the most hardened of British prisoners exiled to Australia.) The discovery of this vegetatively plush side of Australia made the sixth continent appear useful to Britain. The Dutch had discovered Australia on the western side and gave it up as a useless barren wasteland.

Perhaps the most important discovery on this first exploring expedition of Capt. Cook was the diet he invented for his sailors, that of fresh beef, fresh fruit, fresh vegetables, and onions with sauerkraut as the daily staple. Before such a diet, it was common for voyages to leave a European port with a fleet of three or more ships carrying more than three hundred men with stores for three to five years and return from the East Indies with valuable spices. Tragically, such a voyage also returned with less than a third of the original crew with more than two hundred men succumbing to scurvy. Capt. Cook, after leaving Australia, entered the Dutch port of Batavia (Djakarta) to take on fresh supplies without a single death and no report of scurvy. The diet, high with fresh fruit and vegetables, helped make Britain the ruler of the waves. However, while in Batavia, twenty three of Capt. Cook's men died of dysentery which was traced to the disease infested stagnant canals of the tropical Dutch port where the transplanted traditions of Holland brought to the tropics took their toll.

Capt. Cook commanded a second national exploring expedition from 1772-1775 with the express purpose of finding the southern polar continent. He sailed on the H.M.S. RESOLUTION with 118 men and was accompanied by the H.M.S. ADVENTURE with eighty three men. Andrew Sparrman, a biologist and a student of Linnaeus, was the chief scientist taken along, and again an overwhelming number of specimens of plants and animals were collected for British museums for the expansion of scientific knowledge. Capt. Cook jammed his two ships through some of the most dangerous seas imaginable actually crossing the Antarctic circle three times--on January 17, 1773 at 40 degrees East Longitude, on December 15, 1773 at 150 degrees West Longitude, and in January of 1774 at 107 degrees West Longitude. He spent 117 consecutive days facing bitter freezing sea spray which turned his sails into ice sheets like iron. Where the sea was not frozen and his ships could move, he faced continual gale force winds and heavy seas. He saw immense tabular icebergs never observed before, even in the Arctic, and frequently became trapped in pack ice. Capt. Cook entered in his ship's log:

"Our ropes were like wires, sails like boards or plates of metal and the sheaves frozen fast in the blocks so that it required our utmost efforts to get a top sail up or down. The cold is so intense as hardly to be endured, the whole sea in a manner covered with ice, a hard

gale and a thick fog. Under all these unfavorable circumstances it was natural for me to think of returning more to the north."

He was the first to completely circumnavigate the Antarctic region penetrating the Antarctic circle several times and finding no Southern Hemisphere continent extending into this region, concluded that a southern continent did not exist.

On the return to England, Capt. Cook discovered South Georgia Island, naming it after his beloved king in 1775. The H.M.S. RESOLUTION, on which Capt. Cook sailed, returned to England without a single death due to scurvy. On the H.M.S. ADVENTURE Capt. Furneaux failed to keep his crew eating a rigid diet of sauerkraut and buried twenty one men at sea. Other scientific discoveries as a result of the trip were the mapping of the distribution of newly found races of the Pacific such as the Maoris, the Aborigines, the Melanesians, and the Polynesians. Several active volcanoes were also surveyed.

A third scientific exploring expedition was sent out by Britain from 1776 to 1779 with the objective of finding a northeast passage between the Atlantic and the Pacific Oceans. Capt. Richard Pickersgill on the H.M.S. LION was to penetrate the Arctic Ocean from the Atlantic side, and Capt. James Cook was to do the same from the Pacific Ocean with a planned rendezvous north of Russia sometime in 1778. Both penetrations failed. Prior to the attempted penetration through the Bering Strait, Capt. Cook discovered Christmas Island and the Hawaiian Islands and constructed detailed maps of the west coast of North America from northern California to the Bering Strait. On the homeward journey Capt. Cook resupplied in Hawaii. In a skirmish with the Hawaiians, he was killed. The Hawaiian natives themselves were shocked at the death of a fine leader and warrior. They held Capt. Cook in high esteem and to honor him, as was their custom for all honored men who died in battle, they probably ate him, returning to his ship only a few ceremonially-cleaned bones. The greatest contributions of Capt. Cook's life's work gave Britain a detailed and correct map of the world and a diet that permitted sailors to live at sea long enough to study that world.

With the English navies being tied up in the War for Independence by the American Colonies and the French and Dutch giving arms and encouragement to those colonies in order to embarrass England, further British exploration was curtailed. The French, pursuing similar exploring interests as the British, sent out an expedition under the command of Jean-Francois La Perouse. He attempted to find a northwest passage through the Arctic Ocean, planning to sail north of Alaska and Canada, from the Pacific Ocean side in 1785. Failing to penetrate into the Arctic Ocean, he explored the western Pacific, collected specimens of rocks, plants, and animals and mapped the coasts of Japan, Korea, and China. He discovered a passageway between Sakhalin and Hokkaido. He sent his logs and specimens back to France from Petropavlovsk in Kamchatka and was last heard from while visiting Botany Bay in Australia in 1788.

In 1789, war between France and England erupted and lasted until Napoleon's army was defeated by Wellington at Waterloo in 1815. During the long global struggle, naval warfare was fought on every sea of the earth. England became the super naval power, destroying the French and Spanish navies everywhere. Lord Nelson became famous for defeating the French in the battle of the Nile in 1798 and has become a legend by commanding all men of his fleet at Trafalgar, "England expects that every man will do his duty." At the end of that battle on October 21, 1805, Nelson had lost his life, but France and Spain had lost their navies. During these years, exploration ceased until the global war for the colonies and the seas was over.

After the war, Dumont d'Urville commanded several French exploring expeditions. One

of them was to the South Pacific from 1826 to 1829 with one additional objective--to find La Perouse. Like the British exploring expeditions, Dumont d'Urville returned to France with more than 1600 plant and animal specimens and 900 rock samples. On a second exploring expedition from 1837 to 1840, Dumont d'Urville, in search of the South Magnetic Pole, sighted and named Adelie Coast near 140 degrees East Longitude right at the Antarctic Circle.

During the same time from 1838 to 1842, Lt. Charles Wilkes with a fleet of six ships commanded the United States exploring expedition. It was the first such enterprise supported with U.S. congressional funds. Like the British and the French exploring expeditions, a great many rock, plant, and animal specimens were collected. Coastlines were carefully mapped. (Wilkes' coastal maps of Oregon proved useful to his young nation in its dispute with England over the Oregon Territory.) With guidance by Louis Agassiz, the young American scientists Augustus Gould, Asa Gray, and James Dwight Dana became world renowned in reputation as a result of their scientific work with specimens brought home by Lt. Wilkes. In spite of the late date of Wilkes' expedition, 203 actinoid zoophytes and 229 coral zoophytes were identified as new species never seen before. They were named and classified by Dana.

Lt. Wilkes was capable of penetrating the Antarctic pack ice farther than Capt. Cook and from the USS FLYING FISH, he sighted land of over 900 miles of confirmed coastline between 165 degrees and 100 degrees East Longitude and saw exposed mountains and steep down-sloping glaciers of immense size. Although other small land exposures had been seen in the Antarctic since Capt. Cook's expeditions, these sightings by Lt. Wilkes for such a large geographical extent confirmed for the world the existence of the last continent, Antarctica.

6. NEWLY FOUND CREATURES, NEW CLASSIFICATIONS AND EVOLUTION

When the thousands of specimens from the exploring expeditions started to flood the museums of Europe, an incredible strain was brought to bear against Linnaeus' classification system. Georges Cuvier (1765-1832), a French naturalist, gave a lifetime of service to teaching and classifying both living and fossil creatures. When he was overwhelmed by the new data from the exploring expeditions, he gave up using Linnaeus' classification system and invented his own. For the animal kingdom, Cuvier saw four great groups. Radiata was a group of jelly fish and star fish. Articulata grouped worms and insects together. Mollusca grouped snails and octopuses. Vertebrata included all animals with backbones. He saw each of these groups displaying an ascendance of order from the simple to the complex showing God's great wisdom and power. The ascendance in all the groups also showed an ascendance to mankind, God's special creation. Georges Cuvier accepted from Linnaeus that all species were fixed and unalterable, but he found that fossils showed very different living things existed in the past when compared with the living flora and fauna found on the earth. In order to maintain the teaching of fixed species and at the same time accept different living creatures in the past, Cuvier logically imagined great catastrophic events as active forces which destroyed the world that existed in the past. Cuvier concluded God created a new world with different species after each such catastrophic event. He claimed that the Noahic flood was one of those catastrophic events.

Jean Baptiste Pierre Antoine De Monet Lamarck (1744-1829), a French naturalist, also was overwhelmed by the seemingly infinite variety given in nature as witnessed by the many species of unknown creatures received from the various national exploring

expeditions. Lamarck, like Cuvier, abandoned attempts to use Linnaeus' classification system based on fixed species. The French naturalist saw no clear lines of distinction between the many species and wide varieties among the species and concluded that species were not fixed, but in fact, changed, giving the many varieties collected. Lamarck saw change even from species to species and developed four laws of evolution that highlighted those changes. His laws were published as a preface to HISTOIRE NATURELLE DES ANIMAUX SANS VERTEBRES in 1815.

"I. Life by its proper forces tends continually to increase the volume of every body possessing it, and to enlarge its parts, up to a limit which bring it about."

"II. The production of a new organ in an animal body results from the supervision of a new want continuing to make itself felt, and a new movement which this want gives birth to and encourages."

"III. The development of organs and their force of action are constantly in ratio to the employment of these organs."

"IV. All which has been acquired, laid down, or changed in the organization of individuals in the course of their life is conserved by generation and transmitted to the new individuals which proceed from those which have undergone those changes."

It was Lamarck's example that now exists in nearly every vertebrate zoology text explaining how an antelope on the African prairie may have evolved into a giraffe. As the food supply diminished, the antelope had to reach higher and higher for its food in the trees. Those antelope born with short necks starved and were weak and did not breed. The healthy long-necked antelope remained strong, ran with the herd, and bred to produce more healthy long-necked antelope. Gradually, over many generations, as the same want for food in tall trees made itself felt, the antelope had such long necks that they would be renamed giraffes. Statistically the offspring would keep the new characteristics of their parents.

7. SIR CHARLES DARWIN AND HIS VOYAGE ON THE H.M.S. BEAGLE

Charles Darwin (1809-1882) attended Christ's College at Cambridge where he studied theology. He received his B.A. degree in 1831 and was immediately offered an unpaid position as Naturalist on the H.M.S. BEAGLE commanded by Capt. Fitzroy. The assignment given to Capt. Fitzroy was to continue a British project of charting the South American coast and to achieve accurate positions for longitudes by a series of chronological reckonings around the world.

The H.M.S. BEAGLE set sail in September of 1831. Charles Darwin was overwhelmed in the excitement of the expedition that would not bring him back to England until 1836. He witnessed his first active volcano at the Cape Verde Islands, made note of the destructive forces involved, and examined extremely fertile soils on the slopes of inactive volcanoes seemingly formed from the older eruptions. Six hundred miles off the coast of Brazil at St. Paul's Rock, Darwin was sickened by the ease at which sailors clubbed to death boobies and terns not accustomed to human beings.

Darwin was excited at seeing the rainforest and collecting plant and insect specimens. He recorded a fight to the death between a pepsis wasp and a lycosa spider. Victory was easy for the wasp once the spider was drawn away from its natural camouflage. Again and

again Darwin recorded the battle between predator and prey as beautiful endless rhythm. He became interested in how the weak creatures relied on camouflage. He found a phasmid stick that was an insect resembling a twig and a harmless moth that looked like a scorpion. Darwin noticed how a beetle with the colors of poisonous fruit saved itself from birds. Moths with windowed wings looked like dead leaves. The cosmid moth was camouflaged as dead flowers. Still other moths had glaring luminous false eyes on their wings. A heliconian was distasteful to birds while much tastier insects mimicked its colorage.

Continuing the voyage, Darwin witnessed the slave trade and felt he could not support such cruel treatment with Bible passages as most businessmen did who earned their living by slave trade. Here Darwin saw through his Victorian eyes how the strong overcame those he felt were unintelligent and weak, all justified by enforced obedience. He saw in nature the same cruelty when migrating birds abandoned their offspring rather than linger when the cold autumn suddenly set in.

At Puata Altu, in an erosion-torn bank of clay and gravel, Darwin found the fossil remains of a huge megatherium, a giant sloth with very large claws and a head like a hippopotamus. This creature was unknown to the zoologists of his day. He also found fossils of a toxodon (a giant armadillo), a mylodon (an extinct elephant), a guanaco (a wild lama as large as a camel) and many others, all embedded in the gravel mixed with sea shells. All of them were non-existent in Darwin's time; yet they resembled smaller creatures he had seen. With his religious training in his background, he wondered if similar larger creatures had all been taken on Noah's ark. Doubt overwhelmed him.

Finding fossils of horses along the east coast of South America was extremely strange since no horses were thought to have existed in the New World until the Spaniards came to settle and conquer South America. To Darwin, the fossils showed a very different world--a world that changed, a world that probably continually changed as a continuous creation and not a sudden creation of six days. Reasoning first as Carl Linnaeus, that species were fixed, Darwin wondered why so many species were exterminated. Darwin ruled out climatic change. Showing the influence of Charles Lyell's first volume of PRINCIPLES OF GEOLOGY released in 1830, Darwin hypothesized that the Isthmus of Panama was a recently formed land bridge emerging out of the sea. Working from these new thoughts, Darwin abandoned Linnaeus' fixed species in favor of Lamarck's law of evolution and further reasoned that the South American animals may have evolved in isolation until the Isthmus of Panama emerged.

Darwin's first impression of the natives on Tierra Del Fuego was totally negative. He saw them as nearly wild animals and he feared them. He saw the children beaten for minor infractions of tribal law and also witnessed considerable hostility over food needs. In Tierra Del Fuego, Darwin became a firm disciple of Lyell when he saw the land mass in an endless struggle between glaciers grinding down the land and the shoreline continually beaten by exceptionally violent seas. Rain and snow with gale force winds were perpetual there.

While Capt. Fitzroy did extensive surveying and before the BEAGLE turned into the Pacific Ocean, Darwin, on his own, explored the Pampas, a wide prairie spreading over most of southern Argentina. He rode and hunted with the Gauchos, a sort of wild, but civilized Argentinean cowboy. While on the Pampas, Darwin continued to collect geological specimens and more plants and insects. He found that the waterless plain supported very different kinds of birds and made particular note of the rhea being similar to, but slightly smaller than an African ostrich and classified it as "rhea darwini." Darwin also marched with General Rosas who slaughtered South American Indians during a land

clearing operation, all justified by a Christian ruling government. On the Pacific side of South America, upon sighting a rookery of jackass penguins (penguins that brayed like a donkey), Darwin made note that penguins used their wings as fins like a fish while some geese used their wings as paddles and ostriches used their wings as sails.

Darwin climbed the Andes Mountains while Capt. Fitzroy continued the careful slow surveying of the South American coastline. To Darwin's amazement, he found a sea bed filled with fossil sea shells at 12,000 feet above sea level. Farther down the slope at 7,000 feet above sea level, he found a small forest of snow-white petrified pine trees surrounded by marine rocks. Following Charles Lyell's PRINCIPLES OF GEOLOGY, Darwin interpreted those trees as having once been on the shore of the Atlantic, but then in Darwin's lifetime, that ocean was seven hundred miles away. In the distant past that pine forest shoreline must have sunk beneath the sea and once again, after being fossilized, was raised to the visible level of 7,000 feet above the sea. Darwin surmised the entire Andes Mountain range must have been lifted up through movements brought on gradually by volcanoes and earthquakes.

Quite dramatically Darwin became a witness to the very phenomenon he imagined to be involved with the uplifting of the Andes Mountains. While at sea on January 18, 1835, from the Bay of San Carlos, Darwin watched the start of the sudden massive eruption of Mt. Osorno a hundred miles inland. On the same day the volcanoes of Aconcagua and Coseguina, 480 miles and 2700 miles north respectively, also erupted. While visiting the port city on Talcahuano Bay on Feb. 20, 1835, Darwin recorded in his journal the following events:

"10:00 A.M. A large flight of sea birds flew inland and the dogs of the town took to the hills."

"11:00 A.M. An unusually strong sea breeze rose."

"11:40 A.M. Small shocks began, in a few seconds the stable earth violently twisted and foot wide fissures opened and closed again. The sea drained out of Talcahuano Bay."

"12:10 P.M. An enormous wall of water rose sweeping across the port city leaving utter destruction. Many towns in the highlands were leveled by the quake."

Two to three shock waves per hour continued for the next week. When the BEAGLE returned to pick up Darwin, Capt. Fitzroy's survey team confirmed that the entire land mass had risen a few feet. Darwin reasoned that the force behind such earthquakes came from the molten interior of the earth. The crust of the earth was subject to being flexed as the magma underneath moved naturally. He felt such earthquakes were the result of natural occurrences and not a judgment of an intervening God.

The H.M.S. BEAGLE left the coast of South America and proceeded westward visiting the Galapagos Islands. It is on these islands that Darwin's evolutionary theory became complete. He saw for the first time giant tortoises which lived for centuries. He identified land iguanas with clawed feet for climbing. He also noted the existence of nearly identical marine iguanas on the coast of the Galapagos Islands that never went inland more than ten feet. These marine iguanas would indeed flee toward land in fear of sharks, but generally stayed in the water swimming after their food. They had webbed feet.

In the small region of the Galapagos Islands, far removed and isolated from mainland South America, Darwin identified four different species of finches. All the finches had similar dull colors blending in with the black lava rocks, black sands, and the green sea

mosses. All finches similarly gave unmusical sounds. They all had short tails; they all built nests with roofs; and they all laid white eggs with pink spots with four eggs to a clutch. The beaks of the four species of finches were distinctly different (FIGURE 19.2, Sketches after Alan Moorehead, DARWIN AND THE BEAGLE, page 203). One species of finches had strong thick beaks which they used for cracking nuts and seeds. The finches with smaller beaks were able to catch insects. A third species of finches had beaks suitable for eating fruits and flowers. And a fourth species of finches used small, very narrow, and sharp beaks for probing grubs out of small holes.

Already in 1835, as stated in his diary, Charles Darwin had developed his mechanism for evolution. Changes in species occurred by adaptation through successive generations while competing for food and territory. The isolation of the Galapagos Islands allowed the evolution of the finches to go in separate directions. The origin of species was by a natural selection, a survival of the fittest directed by nature itself. These ideas Darwin kept to himself until friends pushed him into going public from the pressure of being scooped by Alfred Russel Wallace who returned from a similar voyage and experience along the Amazon River some twenty years later. In 1858, before the Linnaean Society, both Wallace and Darwin presented their views on "Laws which Affect the Production of Varieties, Races, and Species." The next year Charles Darwin published the ORIGIN OF SPECIES BY MEANS OF NATURAL SELECTION OR THE PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

" . . . amongst organic beings in a state of nature there is some individual variability: indeed I am not aware that this has been disputed. It is immaterial for us whether a multitude of doubtful forms be called species or sub-species or varieties; what rank, for instance, the two or three hundred doubtful forms of British plants are entitled to hold, if the existance of any well-marked varieties be admitted. But the mere existence of individual variability and of some few well-marked varieties, though necessary as the foundation for the work, helps us but little in understanding how species arise in nature. How have all those exquisite adaptations of one part of the organisation to another part, and to the conditions of life, and of one organic being to another being, been perfected? We see these beautiful co-adaptations most plainly in the woodpecker and the mistletoe; and only a little less plainly in the humblest parasite which clings to the hairs of a quadruped or feathers of a bird; in the structure of the beetle which dives through the water; in the plumed seed which is wafted by the gentlest breeze; in short, we see beautiful adaptations everywhere and in every part of the organic world."

"Again, it may be asked, how is it that varieties, which I have called incipient species, become ultimately converted into good and distinct species which in most cases obviously differ from each other far more than do the varieties of the same species? How do those groups of species, which constitute what are called distinct genera, and which differ from each other more than do the species of the same genus, arise? All these results . . . follow from the struggle for life. Owing to this struggle, variations, however slight and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be inherited by the offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection, in order to mark its relation to man's power of selection. But the expression often used by Mr. Herbert Spencer of the Survival of the Fittest is more accurate, and is sometimes equally convenient. We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulation of slight but useful variations, given to him by the

hand of Nature. But Natural Selection, as we shall hereafter see, is a power incessantly ready for action, and is as immeasurably superior to man's feeble efforts, as the works of Nature are to those of Art." (Charles Darwin, ORIGIN OF SPECIES, Chapter III, 1859)

Charles Darwin's work of over twenty years was masterfully presented in the ORIGIN OF SPECIES. It was the first unified approach to biology and provided a paradigm for biological development by natural means which never existed before. In the scientific community, dedicated to the study of nature by experiment and reason, the ORIGIN OF SPECIES was a great success. Darwin became the Copernicus of biology.

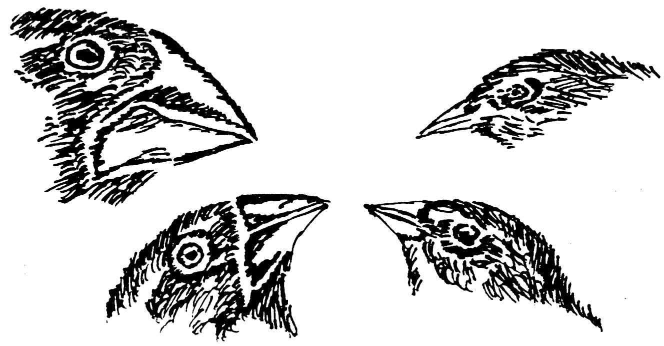

FIGURE 19.2 A COMPARISON OF BEAKS OF FOUR SPECIES OF GALAPAGOS FINCHES.

Many of Darwin's ideas were confirmed for him when the H.M.S. BEAGLE reached Australia after leaving the Galapagos Islands. The different forms of life symbolized by the kangaroo confirmed evolution on an isolated continent. The Aborigines, hunted as animals by some Europeans, confirmed for Darwin the initial ideas for the DESCENT OF MAN which Darwin published in 1871 when he applied the laws of evolution to man.

Along the Great Barrier Reef of Australia, Darwin verified Sir Charles Lyell's theory on the growth of coral atolls. Coral polyp could not live at the great depths, in places more than 120 feet, at the base of such reefs. Lyell and then Darwin showed that the ocean floor was shallower when the reefs were started. The rim of the cone of a volcano would sink slowly while the coral built upwards keeping pace with the changing sea level. The active living coral polyp only existed on the top layers.

The BEAGLE returned to England in 1836. The three volumes of Charles Lyell's PRINCIPLES OF GEOLOGY were complete already in 1833. Lyell had labeled the eras of geology the Eocene (dawn of recent), the Miocene (less of recent), and the Pliocene (more recent). Charles Lyell's and Charles Darwin's careers pushed and stimulated each other just as Sammy Sosa and Mark McGwire chased each other with back-to-back home runs. Geology and biology as interpreted today are inseparable. Discoveries in geology give meaning to biology and visa versa. Darwin's evolution provided great insight in many fields of science. In medicine vaccines are possible with the understanding of the evolution of viruses. Agricultural sciences, with the wondrous growth in food production, would not have been possible without Darwin's view of changing species followed by the discovery of genes and hereditary influences. Mineral exploitations developed through prospecting by principles of geology have provided the industrial nations the raw materials for their growth and given us the comfortable, healthy way of life that is taken for granted in the twentieth century. Our Lord daily showers many blessings on all of His creatures whether they honor Him or not. Despite what God does for all people, men of science deliberately moved their scientific thought apart from religious thought and welcomed the separation as did the ancient Greeks at the origin of science.

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SEPARATE FROM HIS WORD

WHERE IS THE CREATOR?
A Century of Debate About Evolution, Chapter 20

While Charles Darwin was at sea on the H.M.S. BEAGLE, astronomical measurements of extraordinary precision were being made elsewhere. Finally astronomers were arriving at an answer never given since Aristotle asked the question--if the earth moved, then where was heliocentric parallax? At the Cape of Good Hope, T. Henderson, a British astronomer, measured an annual oscillatory change of position of the star Alpha Centauri. It was an extremely small angular change, 0.760 seconds of arc, but it did demonstrate heliocentric parallax. A similar sighting was witnessed by F. W. Bessel who was an astronomer in Germany. The parallactic shift of the star 61 Cygni, seen from the Northern Hemisphere, and the same shift of Alpha Centauri in the Southern Hemisphere confirmed, once and for all, that the earth, in fact, moved around the sun once a year. It had taken three hundred years to finally come up with the needed evidence for the theory of astronomy which claimed the earth moved.

When the Pythagoreans, and in particular Philolaus, had developed the first heliocentric models of planetary motion, we recall that Aristotle defeated such ideas with the question of the existence of heliocentric parallax (FIGURE 8.2) which no one could see. Even after the development of Galileo's telescope and Newton's greatly improved reflecting telescope, no such star oscillations were seen. Think of it! Copernicus had proposed his theory, and it was accepted as fact by many in the scientific community for three hundred years without solid confirming evidence. Kepler's laws of planetary motion and Newton's law of universal gravity were built on Copernicus' model of the solar system, which by Darwin's time had existed for three hundred years without answering the fundamental questions.

To be fair, circumstantial evidence could be seen with the telescope, but certainty was always missing. The awesome sight of a hundred thousand new stars which Galileo beheld through his telescope gave him a view so overwhelming that in his conclusions he saw the universe much larger than ever dreamed of before. With this enlarged universe, men of science assumed the stars were so far away that heliocentric parallax could not be seen. Indeed, that assumption proved somewhat correct when the measured angle sought for so long was 0.760 seconds of arc which was a very very small angle (3600 seconds of arc equals one degree). When Bessel and Henderson published their findings, hardly anyone took notice. The motion of the earth as a planet was already accepted without any further question. By the nineteenth century western society was accustomed to believing scientists. Their explanations and inventions from the application of scientific principles were so successful that few doubted any scientific proclamation. Although the witness of heliocentric parallax was important, by the mid 1800s it was not vital, for no one needed convincing that the earth moved.

Christian theologians had been quite comfortable with the harmony between science and religion and were proud of the Christian contributions to science since the time of Robert Grosseteste's directive for inductive reasoning at the University of Oxford. Much was gained in science knowing that all order came from the Creator-God. When the political church pressured men of science to conform to its authority, Galileo, Newton, and others steered science to an independent path. This new path that science took was not seen by the theologians who were comfortable in their dogma. With separate presentations of Alfred Wallace and Charles Darwin to the Linnaean Society in 1858, men of the church

suddenly realized just how separate from God's Word science had become. During the century before, explanations were developed in which land forms and well defined epochs showed a history considerably longer than written history and seemingly very different than the history of recorded physical events in the Bible such as the flood. John Dalton returned the chemical understanding of matter to an atomic explanation. Many scientists used this to explain changes in matter as occurring by themselves without the necessary involvement of God. Going beyond visible changes of species, the evolutionists were philosophically claiming all species evolved by themselves from a common ancestry. Although Darwin had not plainly identified the ancestry of man until he published his book THE DESCENT OF MAN in 1871, the evolution of all species, including man, was obviously implied.

The outcry from the clergy was, at first, deafening. In the QUARTERLY REVIEW of July, 1860, Samuel Wilberforce, Bishop of Oxford, wrote that "the principle of natural selection is absolutely incompatible with the Word of God." He said Darwin was guilty of "a tendency to limit God's glory in creation" and that Darwin's theory "contradicted the revealed relations of creation to its Creator."

At a meeting of the British Association for the Advancement of Science at Oxford in the same year, evolution, as proposed by Darwin, was to be debated. Darwin became ill and could not attend, but he was defended by Thomas Henry Huxley, a professor of geology at the London School of Mines. The debate resolved nothing. Bishop Wilberforce, in a heated part of the debate asked Huxley whether his claim of descendance from an ape was from his father's side or his mother's side. Huxley replied,

"If I had to choose I would prefer to be a descendant of a humble monkey rather than of a man who employs his knowledge and eloquence in misrepresenting those who are wearing out their lives in the search for truth."

The religious outcry came from all denominations. Rev. Walter Mitchel, in 1867 in a famous series of addresses to the Victoria Institute in London, declared that "Darwinism endeavors to dethrone God." Cardinal Manning described evolution according to Darwin as "a brutal philosophy--to wit, there is no God, and the ape is our Adam." (ESSAYS ON RELIGION AND LITERATURE, London, 1865)

1. SCIENTIFIC OBJECTIONS TO EVOLUTION

Opposition to Darwin's evolution by natural selection was not only from the religious sector, although it was the loudest and caused the most commotion. In the scientific community there was also strong dissension. In the slow, quiet debates conducted in technical scientific journals, many questions were legitimately raised. Sir Joseph Dalton Hooker (1817-1911), a brilliant botanist and a masterful writer, strongly objected to the concept of species changing. Hooker developed considerable expertise with plants through long British exploring voyages on the H.M.S EREBUS and the H.M.S. TERROR from 1839 to 1843 while researching plants and their struggle for existence in the Antarctic and the surrounding islands. Hooker wrote the definitive volumes on plants of New Zealand, FLORA NOVA-ZELANDIAE in 1853.

Knowing most plant species and their varieties, Hooker argued for the permanence of species in plants. From his observations, Hooker concluded that the degree of changes in species of plants from natural influences was insignificant. Those agricultural changes witnessed could not be considered as support for changes like Darwin's natural selection because of the extreme control by the horticulturist. By tracing widely dispersed species

of plants to different parts of the world, and especially to isolated islands, Hooker observed that their characteristics remained unchanged. He concluded that plants were confined within well-marked limits. He observed that large varieties of nearly similar species in plants, even when grown very close together, kept their distinct differences. Widely distributed species had the widest spread of varieties, but, at the same time, they displayed the strongest resistance to environmental change. The lowest or simplest species of plants were the most widely diffused throughout the world. Hooker argued that if evolution by natural selection really worked, such primitive species should be extinct, or at least reduced in number and narrowed to confined environments. He further argued that the newer species, which presumably evolved to survive better, should be more widespread. Instead, the more complex species appeared more confined by their environment and more in danger of becoming extinct. Finally, no plant from a different climate had been capable of adapting to England's climate in spite of the fact that many plants had been routinely brought to England from their distant environments by various exploring expeditions for more than a century.

Opposition to Darwin's view of changing species also came from one of America's leading scientific scholars, a Swiss immigrant who was the first professor of science at Harvard University, Louis Agassiz (1807-1873). Agassiz was an expert on the classification of fossil fish and published many books and journal articles while in Switzerland. He also had an interest in mountain climbing and worked extensively at Unteraur Glacier where he formulated his famous ice age theory. In 1837 he announced his conclusion that Europe was once in the distant past covered by a continental glacier similar to that of Greenland and Antarctica. The European Glacier originated over Scandinavia and pushed outward to the Caspian Sea and to the Mediterranean Sea. Such conclusions were published in ETUDES SUR LES GLACIER in 1840 and SYSTEME GLACIAIRE in 1847.

In 1849 Louis Agassiz immigrated to the United States and accepted a professorship of zoology at Harvard the next year. He joined a government surveying expedition of the United States which was commissioned to map the region around Lake Superior and was excited to discover the great many evidences for the ice age in Minnesota, Wisconsin, Michigan, and Ontario. He was pleased with Charles Wilkes' findings of the icebound continent of Antarctica and claimed that the glacial advance of the Southern Hemisphere moved as far north as Brazil. Louis Agassiz saw one major advance of the ice age from both poles as a result of a sudden mysterious drop in temperature. He believed the Alps were formed by an upheaval due to the sudden convulsion of the land under the heavy ice sheet over northern Europe. Evidences were many. With continual observations of glacial movements of present-day glaciers, Agassiz traced land forms to glacial ice activity. Land forms with striated rocks, large misplaced boulders, and many under fit streams, all marked where the glaciers had been. Kettle lakes, extensive gravel filled drumlins and eskers, and lateral and terminal moraines were proof positive to him of where the glaciers had been, how large they were, and how they moved as "God's great plow."

In the middle of the nineteenth century Agassiz' view appeared quite separate from God's Word, especially when Agassiz rejected the Noahic flood in favor of his glacial interpretation for the land forms seen on the earth's surface. Once the religious furor over Darwin erupted, Agassiz' ice age was also identified as a threat to the church's teachings. A sad reality for conservative church bodies was, that, with such a rejection of the ice age theory, they also refused to listen to the other ideas the great American immigrant from Harvard had to say about evolution.

During his first year at Harvard, Agassiz presented a series of lectures entitled "Plan of Creation in the Animal Kingdom." Agassiz used his vast knowledge of animal species of both living creatures and fossils to show that a spiritual quality existed as an underlying

design to all things. He said scientists could show a great quantity of interrelated facts, but if they did not appreciate the master plan of the Author, they would not know the relationship that bound all organic life to the Higher Power, and they would know the natural world only partially. During Agassiz' entire life, he always appealed to the need to know efficient and final causes in science. As it turned out, it was a desperate attempt to restore harmonious thinking to science with respect to a creator and nature.

As a critic against evolution, a person of higher qualifications could not have been found. Agassiz was a contemporary of Darwin and an active research scientist in the field of zoology, especially fossils. He had a world-wide reputation, and, in fact, can be credited with making the United States the scientific country that it is. He promoted science education by writing and giving lectures all over the country, always to the general public. He started the science department at Harvard and was involved with the establishment of the American Association for the Advancement of Science and the National Academy of Science. In establishing the principles for studying zoology, Agassiz wrote:

"There is a manifest progress in the succession of beings on the surface of the earth. This progress consists in an increasing similarity to the living fauna, and among the vertebrata, especially, in their increasing resemblance to Man. But this connection is not the consequence of a direct lineage between the faunas of different ages. There is nothing like parental descent connecting them. . . . The link by which they are connected is of a higher and immaterial nature; and their connection is to be sought in the view of the Creator himself, whose aim, in forming the earth, in allowing it to undergo the successive changes which geology has pointed out, and in creating successively all the different types of animals which have passed away, was to introduce Man upon its surface. . . . In the beginning the Creator's plan was formed, and from it He has never swerved in any particular. . . . To study . . . the succession of animals in time, and their distribution in space, is therefore to become acquainted with the idea of God himself." (L. Agassiz and A. A. Gould, PRINCIPLES OF ZOOLOGY, Boston, 1848, pages 417-418)

In an ESSAY ON CLASSIFICATION, published in London in January of 1859, between Wallace's and Darwin's Linnaean Papers and Darwin's ORIGIN OF SPECIES, Agassiz affirmed a classification system built on the work of Cuvier.

As Darwin's views began to take hold, Louis Agassiz and his ideas were at first by-passed and eventually swept away in an overwhelming tide of interpretation of the facts heaped together according to the paradigm of evolution. Sir Charles Lyell, no longer opposed to the laws of evolution according to Lamarck, published ANTIQUITY OF MAN in 1863 and showed his complete acceptance of Darwin's thesis on natural selection and man's evolving character amidst the evolving landscapes of the earth. In 1871, Sir Charles Darwin followed with the publication of THE DESCENT OF MAN in which he openly proclaimed man's evolution from an ape.

2. EVOLUTION, THE VICTOR OF THE DEBATE

Asa Gray (1810-1888), a Harvard professor of botany, was inspired by the scientific prowess of Agassiz and became a world-class scientist in his own right by being an early supporter of Darwin's evolution by natural selection. Asa Gray classified the flora of North America according to an evolutionary development. He also built one of the largest herbariums in the world. Losing Asa Gray as a close associate over the philosophy of evolution was most hurtful to Agassiz. James Dwight Dana (1813-1895), a geologist and mineralogist with Charles Wilkes on the Great American Exploring Expedition, was likewise an early friend inspired to great achievements in science by Lois Agassiz. But

Dana also turned to evolution in developing a history of the origin of continents and mountain ranges. Dana claimed the mountain ranges such as the Rockies and the Appalachians were first formed as volcanic island arcs. Then, by cooling and contracting, a dome of land between these island arcs rose out of the ocean. Oscillations occurred in the cooling and heating of the sublayers which permitted retreats and advances of the ocean. During such ocean advances, sediments were laid down forming the several sedimentary rock layers of the central region of the continent. Spurred on enthusiastically by Agassiz himself, Dana also developed a keen interest in zoology and fossils. The good working relationship between these two brilliant scientists ended up in a bitter feud over classification methods of the animals. Dana preferred to use the classification system of Linnaeus modified according to evolutionary development from one species into another, while Agassiz insisted that such transformations of species did not exist. Agassiz stubbornly clung to the four great divisions of the animal kingdom according to Cuvier. Where fossils did not match up with modern species, rather than accepting species which evolved from different forms, Agassiz believed in a new creation by the one and only eternal Creator.

Louis Agassiz had established the Museum of Comparative Zoology at Harvard, classified the many specimens according to the system started by Cuvier, rejected evolution by natural selection, and tried to show God's great design. In 1869 Charles William Eliot was elected President of Harvard, and, as president, placed new young vibrant men in key positions in the College of Natural Sciences. Many of these men, graduate students of Agassiz, were well established believers in Darwin's view of evolution and also in the new evolutionary classification system. As an elderly man, Louis Agassiz disappointedly watched the immense cargoes of specimens sent to his museum in his honor. He could no longer keep up with classifying these specimens using his own non-evolutionary classification system. Instead, he had to watch the quick witted youth, who did not understand what was meant by the "Great Design", do the classifying.

In poor health, Louis Agassiz in 1872 took passage as a scientific advisor on the experimental steamship, the U.S.S. HASSLER, which steamed through the Strait of Magellan and essentially retraced the voyage of the H.M.S BEAGLE. Agassiz visited the same Galapagos Islands and witnessed the same finches Darwin did. He raised two serious questions in an article he wrote for the ATLANTIC MONTHLY titled "Evolution and Permanence of Type" when he returned from the voyage of the HASSLER. Agassiz was willing to admit that there was a difference between species of finches on the mainland of South America and the Galapagos Islands. But to Agassiz, the volcanic islands were of very recent origin compared with the continent. Thus, Darwin's changed finches did not require "such unspeakably long periods" of time to change. Agassiz' second serious question related to the earliest and most primitive forms of flora and fauna life which were continually being duplicated in his contemporary times. These primitive forms in both the plant and animal kingdoms remained essentially unchanged in terms of life functions and structure through all apparent ages of the past. Agassiz asked how the evolutionists could write of development from the simple to the complex if the primitive types of life were still in existence. Finally Agassiz concluded:

"The world has arisen in some way or another. How it originated is the great question, and Darwin's theory, like other attempts to explain the origin of life, is thus far merely conjectural. I believe he has not even made the best conjecture possible in the present state of our knowledge." (Agassiz, ATLANTIC MONTHLY, Jan. 1874)

Louis Agassiz died on Dec. 14, 1873, the month before his last publication went to press. Until his death, Louis Agassiz remained a staunch anti-evolutionist, even though in the end he came to realize that the idea of fixed unalterable species of Linnaeus or Cuvier

had failed. His son, Alexander Emanuel Agassiz, became the second curator of the Harvard Museum of Comparative Zoology. Without debate the museum reclassified all of its specimens to the standard system of the age. Evolution, in the eyes of the scientists, had become law. What about the question from Hooker, that no species change had ever been recorded? Just like the early Copernican astronomers, these evolutionists claimed changes occurred so far in the distant past that they could not be seen.

These evolutionary claims for long eons of time did not escape a word of ridicule in the popular literature of the day. Mark Twain wrote:

"In the space of one hundred and seventy-six years the Lower Mississippi has shortened itself two hundred and forty-two miles. That is an average of a trifle over one mile and a third per year. Therefore any calm person, who is not blind or idiotic, can see that in the old Oolitic Silurian Period, just a million years ago next November, the Lower Mississippi River was upward of one million three hundred thousand miles long, and stuck out over the Gulf of Mexico like a fishing-rod. And by the same token any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three-quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of aldermen. There is something fascinating about science. One gets such wholesale returns of conjecture out of such trifling investment of fact." (Mark Twain, LIFE ON THE MISSISSIPPI, 1875)

One tragic footnote in this entire story of the development of modern evolution is associated with Vice-admiral Robert Fitzroy, the commander of the H.M.S. BEAGLE. In 1839 he published two volumes on the NARRATIVE OF THE VOYAGE OF H.M.S.S. ADVENTURE AND BEAGLE. Darwin wrote the third volume. Fitzroy set sail in 1831 taking a scientist, Charles Darwin, and hoped to demonstrate the Biblical account of the creation and other physical world history found in the Bible. He was pleased that Darwin had theological training at Christ's College at Cambridge and he had frequent discussions with Darwin on the BEAGLE. Fitzroy would take the conservative stand of the church, resting on the accepted science of the day, that mountains never moved. The biblical account of a flood had to be explained as a rising of the ocean. Darwin's explanation, in which he always referred to Charles Lyell's concept of moving mountains rising out of the ocean, was unacceptable to Fitzroy. Fitzroy's troubled conscience could find little comfort when his own survey showed, in fact, that the mountains did rise during their encounter with severe earthquakes.

Fitzroy's life was generally a success. He became Governor and Commander in Chief of New Zealand, but his policies favoring the Maoris were unacceptable to British settlers. For this he was recalled. He was granted the post of chief scientist for the newly established meteorological department of the British Board of Trade. He published the WEATHER BOOK in 1863, a major scientific achievement in its day because it brought together a global understanding of weather. Fitzroy trusted his reason and believed that all knowledge must be in harmony with God's Word. Fearfully he followed the evolutionary debate as it exploded in 1859. Using old worn-out ideas of science, Fitzroy utterly failed to overcome the new exciting interpretations of nature by Charles Darwin and Charles Lyell. Only God Almighty can look into a man's soul and judge with mercy so this note cannot end with certainty, but Robert Fitzroy had leaned on scientific reason instead of his Savior. In the end, with a tortured mind and in poor health, Fitzroy took his own life.

3. RELIGIONS CAPITULATED TO EVOLUTION

Once before, when the politically powerful church in Europe stood up against a scientist, against Galileo, the scientist recanted. This time the scientists had two centuries of confidence behind them. Science was supported by nationally funded expeditions and universities grew in reputation on the basis of their espoused scientific views. Agassiz had created the College of Natural Science at Harvard. Darwin's disciples would reform that university and many others. This time around, after an initial squawk, most churches recanted. The men in the churches followed the lead of the scientists. Asa Gray, only a year after Darwin's work, published several essays in the ATLANTIC MONTHLY in 1860 titled "Natural Selection Not Inconsistent with Natural Theology."

"In short, Darwin maintains that the origination of a species, no less than that of an individual, is natural; the reviewer, that the natural origination of an individual, no less than the origination of a species, requires and presupposes Divine power."

John Bascom (1827-1911), an educator and philosopher dedicated to a life's work of liberal theology, published a major work called EVOLUTION AND RELIGION in 1897. In this book he defined the proper spheres of influence for the warring sides which brought most of them together in peace.

"It is the office of science to give fully and accurately the sensuous facts and sequences of the world; it is the office of philosophy to render the rational ideas which are contained in these phenomena; and of religion to disclose the spiritual affections and actions which are incident to insight. Science presents the facts of the world; philosophy interprets them in terms of reason; and religion in terms of spiritual life. Each, in its relation to the other, is profoundly modified by the doctrine of evolution and the truths of each are most clearly seen and enforced in connection with this conception. . . ."

"Evolution also gives a universality to knowledge quite beyond our previous experience--a universality in time, in place, and in fullness. The stimulating power of evolution is due to the feeling it imparts on an ever-enlarging horizon. One is placed by it in the midst of all knowledge. All knowledge rises before him in full tide, and spreads itself like an ocean through all spaces. The hesitancy and stagnation of thought of any one moment are overcome by the volume of energy which everywhere envelops it. The atmosphere is kept pure and stimulating by its own dimensions." (Bascom, pages 4-6)

John Bascom provided a new world view with exciting new horizons, harmonizing both religion and science for all who were willing to abandon their "stagnant" view of the Bible and yield the truth of origins to men of science rather than listen to the old writer, Moses. One church body after another capitulated, conceding Genesis had nothing to say to science about nature which God provided for mankind. Around this philosophy John Bascom took a small school with a limited program and built a major land grant university, the University of Wisconsin at Madison, which became a rival among the best universities of the world. On his faculty were men such as Charles Richard Van Hise, a pioneer in the study of precambrian rocks who pushed the age of the earth back more than a billion years, far beyond the fossil record. Thomas Crowder Chamberlin, also on the faculty, filled in many of the details missing in Louis Agassiz' ice age, interpreting glacial movements of the Pleistocene age and their effect on the Mississippi River Valley. Chamberlin also pioneered work with the deep interior of the earth creating geophysics as a separate discipline from geology.

Oddly, on an outside wall of Bascom Hall, the central building of the University of Wisconsin, overlooking a long glacially formed hill sloping down to State Street and on to

the Wisconsin State Capitol, is a plaque encouraging all students to take what was presented in the classroom for "sifting and winnowing." The plaque ends with the words "by which alone the truth can be found." Never put into the sifter was a quote from Jesus, "If you hold to my teaching, you are really my disciples. Then you will know the truth, and the truth will set you free." (John 8; 31-32, NIV) Aside from passing in front of Bascom Hall every day for eight years and knowing the rich scientific tradition of the University of Wisconsin, that little sign taught me more than most of the lectures. The knowledge of men of science has always been from men struggling by winnowing and sifting their ideas about the workings of nature. It is only through the Holy Scriptures that we know our Savior and are free from the bondage of our reason that desires to teach us a science separate from God's natural world.

We should not be surprised that science, invented by the Greeks to eliminate their gods, ignores or abandons the very Creator that gave the order in nature that man is attempting to explain. You will recall the early Christians hated science for that very reason in Roman times, that science denied the God who created all and maintained all. The Christian religion is the only religion which permits the only harmony possible when they see creation in a literal sense, that God really created all things the way He told us He did and that He still continually cares for it all.

What is surprising is the rapid abandonment of Biblical teachings by many Christian church bodies who followed arguments such as John Bascom's. Other groups have turned to reason in trying to overthrow ideas of science with more science, even taking states, textbook companies, and the public school system to court in order to return to a debate over evolution and creation. There always is a place for debate, but as in the tragic life of Robert Fitzroy, we see trouble with reason alone. Creation is a religious belief. There is no way around that. Science apart from the Word of our Lord can only give an incomplete picture, and resting on the reason of natural man, that picture cannot even be of nature. The reason of natural man will always turn away from our gracious and merciful God. That is as old as sin and will keep ideas of people separate from His Word. A contemporary of Charles Darwin, when facing the challenge of evolution to the Christian's faith wrote:

"The charge is indeed valid that in our efforts to lead the present unbelieving generation back to faith we make no attempt to demonstrate to the world the harmony of faith and science. But we see no reproach in this charge; rather we glory in it, and we will not, by the grace of God, permit anyone to rob us of this glorying. For we are very certain that it is not possible to help the present apostate world with the lie that the divinely revealed truth is in perfect accord with the wisdom of this world; only the preaching of the divine foolishness, of the old unaltered Gospel, can help the world. Paul as well as the history of the church of all ages and of every Christian testified that the "foolish Gospel" is the power of God unto salvation to all that believe, to the Jew first and also the Greek (Rom. 1:16). A person who has been won for Christianity by showing him that Christianity can pass the sharpest probe of science is not yet won; his faith is no faith." (C.W.F. Walther, quoted by Francis Pieper, CHRISTIAN DOGMATICS, St. Louis: Concordia Publishing House, 1951, Vol. I, Page 164, reprinted by permission)

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SEPARATE FROM HIS WORD

THE CERTAIN LAWS:
Maxwell, Pasteur, and Mendelyeev, Chapter 21

1. CERTAINTY OF THE LAWS OF PHYSICS

Isaac Newton had been such a dominant scientific authority, not by his force of personality or dictum, but by his sweeping successes with explanations of the physical universe. Any finding in nature contrary to his explanations was simply ignored by the practitioners of scientific research. A contemporary of Newton, Christian Huygens, tried to explain light as a system of propagating waves, but the idea of waves needed a medium for waves to travel through. Newtonian physics, particularly the universal law of gravity, required that space be a true void in order to permit the planets to travel around the sun endlessly without friction and not permit a gravitational collapse of the solar system. Following a unified approach to physics, light from distant stars, in order to traverse the millions and billions of miles, had to be made of particles since waves could not travel through a void. When it was found that the stars obey Newton's universal law of gravity, all hopes for a Huygens' view of wave theory for light died.

Even when Thomas Young, a century after Newton, in 1789, sent a monochromatic beam of light through an opaque screen with two slits in it and saw an impressive array of bright and dark lines, many physicists remained loyal to Newton's particle theory of light. The phenomenon Thomas Young saw was an interference pattern of light in which light of a single wave length of color crosses over similar waves and alternately amplifies the brightness and cancels the light entirely. Only waves could demonstrate such a constructive and destructive pattern. Colliding particles could transfer momentum and energy between each other, but they positively could not eliminate each other from existence. Waves as disturbance patterns could negate each other. By all tenets of logic, Newton's view of light should have been eliminated. It was not.

Totally apart from the study of light, Benjamin Franklin's work with electricity in 1747 gained notoriety with his explanation of electrical charge build up in a Leyden Jar. He saw electricity as a fluid that existed in all substances. According to Franklin a positive charge showed an excess of electrical fluid, and a negative charge showed the lack of electrical fluid. As studies of electricity progressed, the concept of electricity as a fluid became more and more accepted and, in fact, competed with John Dalton's atomic view of matter. The fluid properties of electricity in all substances departed from an atomic "grainy" nature of matter where concentrated matter was separated by a void. This view of electricity restored thinking of aether again as a form of continuous matter filling all space between all substances of the universe.

Michael Faraday (1791-1867), building on Franklin's work with electricity, developed the concept of a field--the space between electrical charges which could be acted on by electrical forces of attraction or repulsion. To be acted on, the field had to have some properties like a substance in order to transmit forces. Field theory, when applied to gravity, provided a long awaited answer to a discrepancy recognized already by Newton. Nowhere within human experience had any kind of force been exerted "at a distance" on an object from a second object without physical contact, except in the realm of witchcraft. The success of gravity, as a natural law, simply was too overwhelming to challenge it on the basis of a "force at a distance." Faraday's field, with aether as a medium which carried forces formed the needed connecting link providing contact between gravitationally

moving bodies. Mathematics governing the effects of a field provided the same inverse square law for the diminishing of gravitational forces with respect to increased distances as Newton's supposed forces at a distance. Similar inverse square laws also worked for electrical and magnetic forces which Faraday showed to be interrelated. Changing magnetic forces could always make electrical forces and conversely changing electrical forces could make magnetic forces. Fields, when thought of as space--a substance made of aether--provided the connection for the forces.

Even with Faraday's excellent contributions to field theory, older Newtonian methods simply were too strongly ingrained in physics. Gravity as a "force at a distance" still mysteriously worked. When James Clerk Maxwell (1831-1879) took up the study of fields and developed the mathematical models to express fields, though very complex, he showed an extremely wide variety of phenomena that could be explained with fewer principles in a more unified sense. Ockham's razor over the centuries was still sharp. In 1864 Maxwell published ON A DYNNAMICAL THEORY OF THE ELECTRO-MAGNETIC FIELD and in 1873 the TREATISE ON ELECTRICITY AND MAGNETISM. Maxwell showed that visible light was made of electro-magnetic disturbances which were propagated throughout the universe as waves with measurable lengths and frequencies in aether. Instantly Christian Huygens' wave theory of light published as TREATISE ON LIGHT in 1690 became as important to physics as Newton's PRINCIPIA. At the same time, Thomas Young's demonstration of the existence of interference patterns of light became a key experiment showing that light had to be made of waves. Science textbook writers, as they always had done, rewrote their own history showing science as a march to certain truth while ignoring the past errors, false paths, and seemingly very correct interpretations of nature by other laws which were being abandoned.

Aether was a substance of continuous matter that filled all space uniformly. It gave a constant speed for light of 186,000 miles/sec everywhere in the universe where light passed through aether alone. While substances could easily pass through aether, all forms of matter were permeable by aether. Aether provided only an infinitesimal resistance to the passage of matter through it which allowed planets to move without slowing down except over extremely long periods of time such as millions of years. Initially, long periods of time were interpreted as demonstrations of unalterable stable motions. After Hutton, long periods of time were no longer objectionable to most scientists and could explain large scale changes among the planets and stars. Aether was unaffected by gravity, but was the carrier of electric and magnetic disturbances. Aether was that amazing substance that was both extremely hard and had an extremely low density which permitted light its high velocity. This material, though unaffected by gravity, solved a major problem ignored by Newton and his contemporaries. Whereas Newton's universal law of gravity appeared to work, describing the motion of the planets and stars with precision, his law could not explain a force at a distance. Experience demanded that all forces be physically connected in some way to the things they moved. Empty space did not allow for attachment, but aether did.

Maxwell showed that visible light was only part of a wide variety of electro-magnetic waves. Quickly following Maxwell's ideas came the most useful discovery of ultra-violet rays, x-rays, infrared radiation, and waves that would transmit through all of space without wires. This discovery led the way to radio and television communication. The most important part of Maxwell's epic work showed that these electro-magnetic waves, at the speed of light, were the carriers of information for the entire universe. In order to demonstrate this, he presented by reason, not by experiment, two objects some distance apart from each other. Today one could imagine that these two objects could be either two particles within an atom or two immense stars across the universe; such was the universality of Maxwell's arguments. Examining the existence of these two objects, Maxwell could say

that object A was attracted to object B. Newton's third law, still operable, would demand for every action there must be an equal and opposite reaction. Thus object B could be attracted to object A. But Newton had no way for the two objects to "communicate" their existence to each other, much less, changes that objects might have become involved with. Maxwell imagined object A could move to a new position. Newton's forces of attraction would remain static continuing to point in the direction they were before A moved. We face the intellectual crisis that if nature behaves as the laws of Newton with Newton's view of empty space, that universe would be out of balance with A being in a new position and B remaining where it was, still attracted to A where A used to be. Maxwell's reasoning could now overcome this crisis of imbalance.

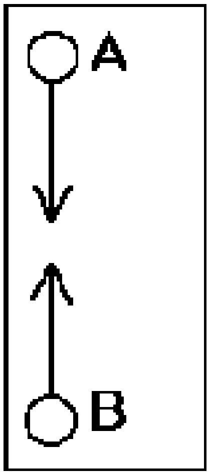
Maxwell's solution showed that the field as a substance changed by forces acting on it. The field responded according to Newton's laws as any other object (FIGURE 21.1, After Robert March, PHYSICS FOR POETS, page 76). When A moved, it pushed on the field. The field in turn pushed back on A equally and oppositely, but the push of the field, when added to the attraction of A to B, redirected that force of attraction changing it so as always to point to the place where B remained while A moved. Over time, at the speed of light, that push by A on the field was transmitted throughout the field. Likewise the force of the field pushing back was transmitted throughout the field at the speed of light in real time and arrived at B. When object B felt the push of the field, it reacted equally and oppositely and pushed back on the field. These reactions were a result of the "knowledge" given to B that A has moved. The vector sum of the attractive force on B to the place where A used to be and the push of B on the field gave the redirected force on B to the place where A had moved.

As a result of Maxwell's field studies, the entire universe was understood completely according to the transmission of light. With light interacting with the field of aether, the presence of all objects, all their motions, and all their interactions, were

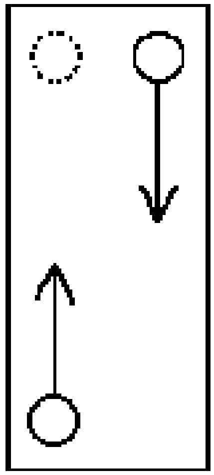
known. For the physicist all the laws of physics were known. Max Planck (1858-1947), when he attended an undergraduate college to study physics, was told that he had chosen a subject that was complete. All the laws were believed to be correctly known and the task of the new scholar in physics would be only to measure with greater and greater precision the constants that bound the universe together.

Conservative church bodies that believed God created and maintained all of nature, and also believed the laws of science, could teach that God created the laws of science. Logically it followed for these church bodies that when people of science had found the laws, they had found true science. Teaching in this manner only solidified the certainty of man's pride. Teaching the existence of a true science repeats the blunders of Thomas Aquinas locking the true doctrines of God to the scientific laws of men. We know too well from history the errors which that mistake caused in the church for many centuries. Historically it is true that by 1873 the certainty of the laws of physics was believed by every scientist. But if the teaching of science is restricted only to what scientists have explained and believe to be correct, then the scientists' own artistry is not seen; how they developed these laws quite separate from God's Word is not seen. Instead, an admiration for the scientist occurs and a love for humanly derived laws is proclaimed. The view of nature and the adoration for the Creator is lost to the laws of science.

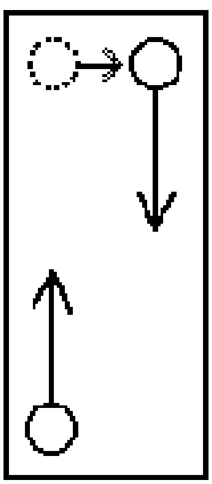
FIGURE 21.1 THE INTERACTION OF A FORCE WITH A FIELD (After Robert March, PHYSICS FOR POETS, page 76).



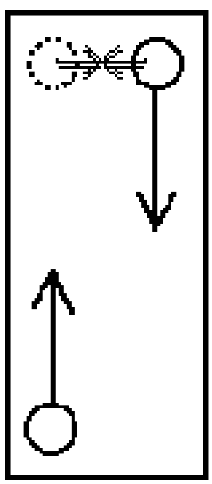
"A" AND "B" DISPLAY A NEWTONIAN BALANCE OF FORCES OF ATTRACTION.



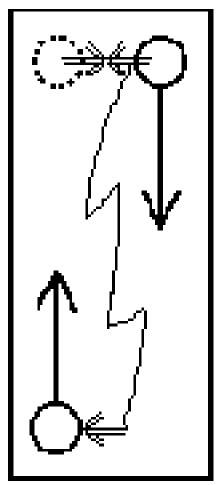
"A" MOVES. THE NEWTONIAN FORCES BECOME OUT OF BALANCE.



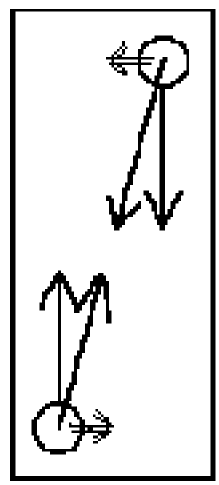
THE MOVEMENT OF "A" APPLIES A FORCE ON MAXWELL'S FIELD.



MAXWELL'S FIELD EQUALLY AND OPPOSITELY PUSHES ON "A".



MAXWELL'S FIELD TRANSMITS AN EQUAL FORCE AT THE SPEED OF LIGHT TO "B".



"B" RESPONDS EQUALLY AND OPPOSITELY BY APPLYING A FORCE ON THE FIELD AND THE FORCES BETWEEN "A" AND "B" ARE BALANCED.

2. THE SEARCH FOR DALTON'S ATOM

The search for the atom took a long circuitous route crossing several fields of science. Failures in medicine allowed meaning to be found for the study a chemist did with wine. Microscopic germs were found. Evolution and studies in heredity led to the finding of genes. With the acceptance of genes it became possible for the scientific mind to accept still smaller atoms. It is this path that we will follow in the search for atoms.

Recall some of the problems chemists had with formulas of compounds, hidden binary molecules, hidden inert gases, confusion of thermal energy with chemical bonding energies, and many others. Advances in science using Benjamin Franklin's electrical fluid and Faraday's field concepts pushed the ideas of the atomic chemist to the side. Maxwell's unification of magnetism and electricity, along with his influence over the universal acceptance of fields of aethereal substance, all but eliminated atomic theory. Chemists worked apart from physicists. The only harmony between these two major branches of science was a belief in a unified natural world. Many chemists, especially those who worked with physics, used atomic theory as a learning tool to experiment on proportional predictive yields in chemical reactions, but they themselves did not believe that atoms, in fact, existed. Nevertheless, direction from research, especially in biology, continued to point to fixed small entities as a base for structure.

3. FAILURES IN MEDICINE

In the 1830s the number of mothers dying from a disease called puerperal fever within a week after giving birth reached epidemic proportions. Oddly enough, statistics began to show that those mothers treated in a hospital by professional midwives and nurses or by professional doctors making house calls had the highest death rate. Mothers assisted at delivery by a midwife who was a relative or a neighbor, a midwife who did not have a very active practice, had the highest chance of surviving and avoiding the dreaded killing fever. Oliver Wendell Holmes, a famous American author, who was a professor of anatomy and a practicing physician, rocked the scientific and medical professions by exposing the chief cause of puerperal fever as the professional doctors, nurses, and midwives themselves.

In those days personal hygiene was almost non-existent, even among the highly educated medical doctors. It was quite common for a doctor to move from patient to patient with the same set of clothes, not cleaned for several months. The doctor would use the same gown for all surgeries, birth deliveries, and prenatal examinations. If one of his patients died, he performed the autopsy using the same clothes and rarely washed his hands before examining the next patient. Holmes collected case studies from individual doctors which showed excellent deliveries and recoveries for the first several mothers that a doctor would attend early in a week, but by the end of a week, deaths would begin to occur among most of the mothers treated or examined by that doctor. They would continue to die until after a few months when the doctor would bathe or wear a different set of clothes. Holmes wrote forcefully:

"The disease known as puerperal fever is so far contagious as to be frequently carried from patient to patient by physicians and nurses. . . . I take it for granted that if it can be shown that great number of lives have been and are sacrificed to ignorance or blindness on this point, no other error of which physicians or nurses may be occasionally suspected will be alleged in palliation of this; but that whenever and wherever they can be shown to carry disease and death instead of health and safety, the common instincts of humanity will silence every attempt to explain away their responsibility. . . . If there are any so far

excited by the story of these dreadful events that they ask for some word of indignant remonstrance to show that science does not turn the heart of its followers into ice or stone, let me remind them that such words have been uttered by those who speak with an authority I could not claim. It is as a lesson rather than as a reproach that I call up the memory of these irreparable errors and wrongs. No tongue can tell the heart-breaking calamity they have caused; they have closed the eyes just opened upon a new world of love and happiness; they have bowed the strength of manhood into the dust; they have cast the helplessness of infancy into the stranger's arms, or bequeathed it, with less cruelty, the death of its dying parent. There is no tone deep enough for regret, and no voice loud enough for warning. The woman about to become a mother, or with her new-born infant upon her bosom, should be the object of trembling care and sympathy wherever she bears her tender burden or stretches her aching limbs. The very outcast of the streets has pity upon her sister in degradation when the seal of promised maternity is impressed upon her. The remorseless vengeance of the law, brought down upon its victim by a machinery as sure as destiny, is arrested in its fall at a word which reveals her transient claim for mercy. The solemn prayer of the liturgy singles out her sorrows from the multiplied trials of life, to plead for her in the hour of peril. God forbid that any member of the profession to which she trusts her life, doubly precious at that eventful period, should hazard it negligently, unadvisedly, or selfishly!"

"What ever indulgence may be granted to those who have heretofore been the ignorant causes of so much misery, the time has come when the existence of a PRIVATE PESTILENCE in the sphere of a single physician should be looked upon, not as a misfortune, but a crime; and in the knowledge of such occurrences the duties of the practitioner to his profession should give way to his paramount obligations to society." (Oliver Wendell Holmes, "The Contagiousness of Puerperal Fever," THE NEW ENGLAND QUARTERLY JOURNAL OF MEDICINE, 1843)

4. THE DISCOVERY OF MICROSCOPIC GERMS

Some small entity that could transmit from patient to doctor to another patient was a carrier of the deadly disease. An understanding of microorganisms and the entire process of isolation and incubation of microorganisms was developed by a French chemist unfamiliar with biology, Louis Pasteur (1822-1895). Before Pasteur became involved with the study of yeast, as a pure research chemistry, he studied the effects of different chemical solutions on polarized light.

If a person uses a polarizing filter on normal white light, the crystalline structure of the polarizer will organize the light waves in an exacting fashion not completely understood in Pasteur's time. The use of an only partly understood phenomenon still permitted great discoveries. When a second polarizing filter is turned in such a way that the polarizing crystals of one filter is perpendicular to the polarizing crystals of the other filter, white light comes through the first polarizer and is then polarized to be completely blocked by the second filter called the analyzer.

Louis Pasteur used a polarizer on normal light which gave him a beam of polarized light. He then passed his polarized light through many kinds of solutions and used the analyzer to look at the light coming through the various liquids. Many liquids had no effect on the polarized light. But some of the liquids rotated the polarized light requiring the analyzer lens to be rotated through larger angles. He thus discovered two entire classes of solutions that gave either a rotation to the right or to the left to polarized light. He concluded that the property of a solution that rotated the plane of polarization of the polarized light was due to the lack of symmetry of the molecules of the substance. He

thus discovered in amyl alcohol the presence of two different isomers, two different alcohols whose molecular structure contained the exact same ratios of composition of elements, but had different molecular structures. Pasteur found a way to identify some of these otherwise hidden different substances by polarizing light. One of the amyl alcohols rotated polarized light while another amyl alcohol did not. The discovery of things like isomers slowed the acceptance of atomic-molecular theory.

Pasteur noticed that only those solutions of chemistry that had come through some life process rotated polarized light. He made good use of this generalization on other problems he was asked to study while a professor of chemistry at the University of Lille. Pasteur was asked to help analyze the fermentation process for the local wine industry which was experiencing problems with fermentation. The fermentation process was believed to be a natural decay process. When sugar was changed to ethyl alcohol, lactic acid was a by-product. Pasteur recognized that a solution of lactic acid would rotate polarized light and concluded that it must be from a living organism.

Pioneering procedures never done before, Pasteur developed what today is called a nutrient culture for the isolation and incubation of a particular microorganism. He extracted the soluble part of brewer's yeast by boiling it in water several hours and filtering out all non-soluble parts. This process killed off any living yeast and separated it from the natural nutrients. The nutrients were added to a sugar and chalk medium. Aided by a microscope, before Pasteur sealed his culture, he drew off from a naturally fermented spoiled wine mixture, a few spots of grey matter associated with lactic acid in the ferment. This grey matter was sprinkled over the prepared sterile nutrient mixture and then sealed. This culture, separate from air, immediately began to ferment under warming incubation at 35 degrees C (95 degrees F). Through a microscope Pasteur watched the mixture become cloudy and the chalk disappear as it reacted with newly formed lactic acid as the sugar was consumed. In the container, gases of carbonic acid and hydrogen built up. Pasteur excitedly watched, at first, very small, then growing, grey globules which he identified as newly grown yeast. At the end of the experiment, the remaining liquid was dissolved and solid calcium lactate confirmed that the lactic acid was formed as the growing population of yeast in a non-oxygen environment fermented sugar into ethyl alcohol and lactic acid. Louis Pasteur showed that fermentation was not a decay process, but the macro view of the activity produced by living microorganisms.

Louis Pasteur continued his research with microorganisms and published his "Memoir on the organized corpuscles which exist in the atmosphere" in 1862. In this paper, Pasteur explained his experiments with which he demonstrated that the air transported microorganisms from place to place, and that yeast, as an example, did not come from spontaneous chemical reactions from non-living compounds, but only from more yeast. Likewise, germs came only from other germs of the same kind and could be transported from place to place by air. He developed several containers holding nutrient sterile cultures, and with them showed that a container, exposed with easy access to air, developed a rapid growth of microorganisms. A container open to the air, but only through a long tube with multiple bends, showed no microscopic growth for days, weeks, months, and even years, even though all nutrients for such growth were available. Pasteur had shown that spontaneous generation of living creatures from non-living matter did not occur, even for the smallest known living microorganisms. Nevertheless, the next generation of biologists will see Pasteur's demonstration of life in a non-oxygen environment as a necessary link in the evolutionary process.

Joseph Lister (1827-1912), a British surgeon, upon reading Pasteur's paper on fermentation, instantly thought of the same spread of germs from patient to patient, from doctor and nurse to patient, and through the air as Pasteur rightly confirmed. Lister

realized microorganisms must likewise be responsible for putrefaction or inflammation of all surgical wounds. The death rates in hospitals were atrocious. Lister learned that in Germany, the putrid stench at sewage plants, also a place for oceans of microorganisms, was cut down by using a newly developed chemical called carbolic acid. Lister reasoned that the carbolic acid killed the microorganisms at the sewage plant and immediately began treating all surgical equipment, all dressings of wounds, and finally even the wounds themselves with a mild dilution of carbolic acid. He found the result astonishing. Death and decay in hospitals was greatly reduced, and Lister today is known as the father of antiseptic surgery.

Biologists and medical practitioners pursued the microorganisms by separating chemicals, isolating the microorganisms in cultures, and studying the growth of these microorganisms in the pure cultures with the aid of microscopes. Different germs were identified for different diseases. Persons of science probed to the smaller and smaller and found no end to the complexity of substructure which hinted at still more substructure.

5. GENES HELD THE HEREDITY OF EVEN GERMS

Gregor Mendel (1822-1884) conducted special experiments with hybrids of peas in order to trace characteristics of heredity. He found that if he could control certain characteristics for one generation of hybrids, then generations thereafter followed certain mathematical ratios. He read his findings to the Brunn Society for the Study of Natural Science in 1865. Mendel was encouraged to repeat his work with other kinds of plants and did so with wild hawk weed. His theoretical predictive ratios with these plants failed. Mendel's mathematical results were thus never recognized as the sought-after missing link for Darwin's changing species by natural selection until long after the death of both men. That mathematics worked at all among such complex species of plants as peas opened the possibility of some hidden underlying structure in organisms of every kind and was in future years called the gene.

W. L. Johannsen first used the term "gene" in signifying a unit of inheritance in 1909. The following year Thomas Hunt Morgan began to work with fruit flies by showing hereditary relationships and linked them to unseen genes. In 1912 A. H. Sturtevant mapped genes as segments of a chromosome. The drive for understanding substructure enhanced the hopes for a useful atomic theory even though acceptance of this theory had been difficult in the last century of science. After John Dalton's work, a century of confused chemical data had to be beaten into submission. The master at forcing such a solution, finding untold order, was a Russian professor of chemistry at St. Petersberg, Dmitri Mendelyeev.

6. THE PERIODIC CHART

Prof. Menshutkin read a paper written by Mendelyeev to the Russian Chemical Society on March 6, 1869 on "The Dependence between the Properties and the Atomic Weights of the Elements," and then unveiled a large chart which today, with only slight revisions, is called the Periodic Table of the Elements (Figure 21.2). Mendelyeev had been committed to Dalton's atomic theory and Dalton's insistence that the weight of an atom of an element held the key to the properties of each element. Following such a directive, with poetic license, Mendelyeev arranged the elements according to literally thousands and thousands of descriptions of chemical compounds. He arranged fifty-six elements in order of their atomic weights and also according to his recognized periodicity of chemical

properties. For example, Mendelyeev recognized the second and ninth elements of his list, lithium and sodium, resembled each other as elements, reacted with other elements according to similar ratios, and their respective compounds all had similar properties. In constructing his chart, Mendelyeev arranged elements with both similar chemical properties and similar weights in the same group such as platinum (196.7 amu), iridium (197 amu), and osmium (198.6 amu) in group VIII, where amu stands for atomic mass units, a unit of weight equivalent to one hydrogen atom. Elements were arranged from left to right horizontally with increasing weight, and the successive rows would start so as to group heavier elements with similar chemical properties under the lighter elements. Here is where the periodic properties show up. Potassium (39 amu) begins a row with the lowest atomic weight of that row. Under potassium, starting another row, was placed rubidium with 85 amu. Under rubidium Mendelyeev placed cesium with 133 amu. Mendelyeev noted that successive differences of weight were near 47 amu with three of the elements in this first column group. All elements in group I needed two atoms to combine with oxygen. These similar chemical properties were the great predictive insight for determining all chemical properties that Mendelyeev hoped for from his periodic chart.

H 1																
Li 7	Be 9											B 11	C 12	N 14	O 16	F 19
Na 23	Mg 24											Al 27	Si 28	P 31	S 32	Cl 36
K 39	Ca 40		Ti 43	V 51	Cr 52	Mn 55	Fe 56	Co 59	Ni 59	Cu 63	Zn 65			As 75	Se 78	Br 80
Rb 85	Sr 87		Zr 90		Mo 96		Ru 102	Rh 104		Ag 108	Cd 112	In 113	Sn 118	Sb 122	Te 125	I 127
Cs 133	Ba 137			Ta 182	W 184		Os 195	Ir 198	Pt 197	Au 197	Hg 200	Tl 204	Pb 207	Bi 208		
			Th 231		U 240											

Figure 21.2 The modern Periodic Chart is shown here with Mendelyeev's blank spaces. All atomic weights are from Mendelyeev. The placement of all elements except thorium and uranium are in agreement with the modern chart.

The periodic chart as an artist's invention was not an instant success. Remember, atomic theory, to begin with, was not universally accepted. What was most displeasing to the audience of chemists was that Mendelyeev had left blank spaces in the chart even though no such elements had been found. The charge at that time was justifiably made that Mendelyeev could not leave blank spaces where nature had none. It was felt to be an unethical practice to leave such blanks just so his explanation would work. Mendelyeev had also done much more than just leave some blank spaces in his chart. He took known measurable atomic weights and altered them, even altered them drastically, to make the elements fit the periodic order he imagined to exist. Indium was changed from 75.6 amu to 112 amu. Thorium was changed from 116 amu to 232 amu, and uranium was changed from 120 amu to 240 amu.

Faced with the early rejection of the periodic chart, Mendelyeev predicted that the blank spaces would be filled in as new elements were discovered. His newly formed law of periodicity, he claimed, would even predict the properties of those unknown elements

before they were found. In Mendelyeev's 1871 Periodic Chart, group III showed two blank spaces, one under boron and one under aluminum. A modern chart would show one of these blank spaces in group IIIA and the other in group IIIB. The element under boron Mendelyeev named ekaboron, predicted its atomic weight to be 45 amu, and said it would have a metallic appearance with a density of 3 grams/(cm cubed). He also predicted the chemical formulas for several compounds with ekaboron, Eb two O three and EbCl three. Eka-aluminum was predicted to have an atomic weight of 68 amu with metallic properties and a density of 6 g/(cm cubed). Eka-aluminum would give similar compound formulas as ekaboron, Ea two O three and EaCl three. The blank space under silicon was called ekasilicon and predicted to have 72 amu, a density of 5.5 g/(cm cubed), and compound formulas such as EsiO two and EsiCl four. Mendelyeev thought eka-aluminum and ekasilicon, both being volatile, would be easy to find using spectral line studies of their respective gases. He further predicted ekasilicon would be found in nature among compounds of titanium and zirconium. Mendelyeev also claimed ekaboron would not be volatile and thus would prove to be difficult to find. Within a year of his predictions, in 1871, gallium (eka-aluminum) was discovered and today's periodic chart lists its atomic weight as 69.72 amu and its density as 5.91 g/(cm cubed). Scandium (ekaboron) was found in 1879. Its atomic weight and density were 44.96 amu and 3.0 g/(cm cubed) respectively. Germanium (ekasilicon) was discovered in 1886. Its weight was 72.59 amu and it had a density of 5.32 g/(cm cubed). All of Mendelyeev's predictions for chemical bonding of these three unknown elements in his blank spaces proved to be exactly correct.

Mendelyeev's periodic chart, especially with his dramatic predictions, for all practical purposes, clinched the arguments favoring atomic theory. In fact, such periodic order signified substructure to the atoms. In 1897 Joseph John Thomson of England discovered the electron. In 1914 Ernest Rutherford, born in New Zealand, but making his discoveries in England, identified the proton. James Chadwick, also an Englishman, discovered the neutron in 1932. The search for finer and finer substructure continues even today.

Of an interesting note, one blank space from Mendelyeev's 1871 chart at the time of this writing still has not been found in nature. Today's element number 43, technetium, under manganese was predicted by Mendelyeev to have an atomic weight of 100 amu. Using high energy nuclear cyclotrons for bombarding natural elements with subatomic particles, the modern scientists have forced the completion of the chart. Three artificial isotopes of technetium that remain stable have atomic weights of 97, 98, and 99 amu. The periodic chart pushed into existence through the imaginative mind of Dmitri Mendelyeev is today at the heart of all chemistry with no blank spaces, but new artificial elements are continually being added on the outer edges.

7. CHANGES IN OLD LAWS BECAUSE OF ATOMS

Philosophically, science had come full circle with regard to the atoms, although the modern atom, because it had substructure, is quite different than the atom of Democritus. Atomic science, in ancient times as well as now, described nature as deriving all of its order through the mechanics of the atoms. The end of the nineteenth century began to provide clear definitions of heat energy as the summation of kinetic energies of the molecules, and temperature became a measure of the average of the kinetic energies of the molecules.

Laws of thermodynamics, once based on the flow of caloric fluid, were transformed into statistical laws of probability by Ludwig Boltzmann (1844-1906). At one time the physicist

knew his laws of thermodynamics with certainty as long as he believed heat was a substance. Today, believing the universe is made of atoms, the physicist can never have more certainty than the certainty probabilities can give. Material made of atoms is subject to a randomness and the use of the word "always" must be barred from the physicist's vocabulary as long as they accept the atomic world.

Democritus argued away from randomness and statistical chance in favor of atomic interaction by necessity, but our world of science embraces randomness, chance, and probability as part of the explanation of nature. So separate has science become from a Creator-God Who made and maintains all things with order. Ludwig Boltzmann, an early supporter of the evolutionary philosophy of Charles Darwin and a champion of the atomic theory, facing such a world, ended his life by his own hand in despair.

8. TROUBLE WITH THE CERTAIN LAWS

By the 1880s, scientists all over the world were certain of the laws of science. They were looking forward to the next century when their entire way of living would be transformed by the application of the laws of science which would yield technological advances of miraculous proportions. For many of these scientists, it appeared that evolved man had developed the laws of science and found them to be good. The pursuit of knowledge in pure research was not concerned with new discovery, but only with finding the extra decimal place on measurements already known. Such was the work of Albert A. Michelson, a professor at the Case School of Applied Science in Cleveland, Ohio. Together with Edward W. Morley, a chemist from Western Reserve University, they set out on the routine task of measuring the speed of the earth through the aether of space. They intended to do this by sending beams of light simultaneously across the stream of aether and with and against the stream of aether as the earth passed through it in its annual revolution around the sun. Everything was known. The speed of light was an established constant. The speed of the earth and its motion around the sun was an established fact. Maxwell's perfect description of electromagnetic waves, beginning to yield the miraculous new technology, gave the properties of aether with certainty.

The Michelson and Morley experiment became a milestone for displaying the precision possible with the technology of the day. They attempted to outdo everyone before them in order to provide the best measurements possible of the known values they pursued. As they built the Michelson interferometer, every possible error of measurement was negated by compensating tooling. The two light beams, across the stream of aether and along the stream were multiplied by many reflections extending the lines of measurement. The entire apparatus was mounted on a large slab of concrete which was floated on mercury in order to absorb all outside vibrations. Then the entire apparatus was rotated to measure every conceivable angle that the light could be fired across and with the stream of aether. Knowing the speed of the earth, they expected to measure higher velocities for light when the light beam was directed across the stream of aether and back than up stream and back down again. Light against the stream of aether would be slowed and take much longer. Stated in a simpler manner, they expected the measured speed of light to be faster when the earth was traveling into the beam of light and slower when the earth was traveling away from the beam of light.

To their unbelievable amazement, Michelson and Morley, from every conceivable angle, measured the exact same speed for light. That could only mean, with absolute measurements, that the earth was not moving. After the observed small oscillations of nearby stars, wittnessed heliocentric parallax, confirmed the motion of the earth Michelson and Morley had proved the earth was stationary. They presented their

evidence in 1887, two centuries after the presentation of the laws of motion by Isaac Newton and three and a half centuries after Copernicus. The Michelson and Morley experiment was repeated in every major physics laboratory in the world in both Northern and Southern Hemispheres, and every research team measured the same results. The earth's motion was measured as stationary when all the laws of science claimed it was in motion. This was the most negative experiment of all time. Science at its time of certainty was in a crisis.

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SEPARATE FROM HIS WORD

TWENTIETH CENTURY SCIENCE:
"Change and Decay in All Around I See," Chapter 22

As the twentieth century began, science was in a state of disarray and confusion, especially in physics where it had been most certain of its laws ever since the Greeks invented it. Yet to the lay person in science, things could not have been better. By 1900, most church bodies that saw a problem with evolution had found the intellectual words necessary to ignore God's Word and embrace the benefits of the countless new technical professions being created. The great research tools and advances of the past century were being hammered into consumer products and called miracles by both inventor and consumer. The search for the hereditary gene led to miraculous vaccines sparing countless deaths and sufferings. Maxwell's electromagnetic waves were sent across a laboratory without wires and radio was invented. Previously unknown electromagnetic waves labeled x-rays became an important medical tool. Cathode ray tubes, so important in the debate over whether light was a particle or a wave, became efficient fluorescent light bulbs. The bending of a cathode ray tube into a mass spectrometer for the determination of the atomic weight of atoms was brought into every home as a television set, and Mendel's hybridization transformed farming and permitted the urban areas to grow into centers of millions of people. Finally, the common understanding of Mendelyeev's chart along with the ensuing understanding of atomic structure and chemical bonding changed the search for new materials to be found in nature to the creation of materials of human design. These great successes hid from the lay person the confusion and uncertainty that existed behind the laws of science that seemed so correct.

The answers to the crises that arose at the turn of the century came fast and furious, changing the laws even several times. Where human imaginative solutions to complex problems viewed in nature appeared to be overwhelming, even unbelievable at times, some people tried to revert to old ways. Not satisfied with evolution, they tried to return to Karl Linnaeus' system of classification for unchanging species. When the theory of relativity appeared to defy common sense, strong willed personalities tried to hang on to the old Newtonian laws of motion. Some even went to the extreme of returning to a Ptolemaic view of the earth and the motion of the planets above the earth.

Remember that in every case some part of the older views of science did, in fact, fail. Human beings as creatures of God do not have a God's eye view of nature. From our perspective, nature is subtle and often appears to rebel against a human explanation. At other times, the scientist's laws appear unalterably accurate, only to have the clearest, most certain law lead to a phenomenon that will cause the failure of those laws. Laws of evolution exist today because views of fixed species failed. A stationary view of the earth failed. Laws of motion built on absolute measurement failed. The universal law of gravity failed. Phlogiston, caloric fluid, electric effluvium, laws of thermodynamics in a deterministic sense all failed. We can not go back to the old ways, as comfortable as they might have been, because those laws of science failed. The newer laws in conflict with Scripture will fail too.

1. THE THEORY OF RELATIVITY--ALBERT EINSTEIN

When the earth's motion could not have been more certain, Michelson and Morley

showed an apparent stationary earth in the aether of space. In response to this crisis, Albert Einstein in 1905 developed his special theory of relativity as an explanation. Einstein simply accepted Michelson and Morley's results, that the velocity of light comes to all observers in all directions at the same measured speed regardless of the observer's state of rest or motion. Light, as a communicator of all things in the universe, travels at a speed which is a universal constant and cannot become faster. The normal vector addition of velocities, so successful in Newton's laws, simply did not work for high speeds or with any measurement involving light. The velocity of light plus any other velocity, even another velocity of light, still and always added up to the velocity of light, never higher. Measurements compared from different positions, especially from moving platforms, will not be able to give a sequence of events with certainty. An observer could never be sure, for example, of the occurrence of simultaneous events with light arriving at the same speed regardless of the observer's motion.

Velocity is a humanly invented combination of a change of distance with respect to a simultaneous change of time. In Einstein's theory of relativity, the very instruments that measure distance and time are subject to change relative to their motion. The measurement of both time and distance change just enough so that the combination of a given velocity added to the velocity of light then equals the very same velocity of light. In this manner, using Michelson and Morley's technique, the velocity of the earth could never be measured relative to light. As an object moves with a higher and higher velocity relative to other platforms of observation at rest, that object and all things moving with it become shorter in length. At the same time the object's mass becomes greater and its time slower.

During the years of debate that followed, Einstein developed various "thought experiments" that showed the reality of relativity. One "thought experiment" for the relativity of time is given here. Einstein imagined a long train moving along a straight track at an extremely high speed. Two conductors stood at each end of the moving train with watches which they planned to synchronize at the flash of a light in the exact center of the train. Viewed from the moving train, when the light flashed, both conductors simultaneously started their watches. The conductor at the back of the train then walked up to the front of the train to compare his watch with the watch of the conductor assigned to the front of the train. The conductors found both watches to be showing the exact same time. That is what Newton's laws would show also.

However, a viewer at rest, stationary, outside the moving train would see things quite differently. When the light flashed, the stationary viewer at the side of the track saw the light pulse travel in both forward and backward directions reaching the back of the train first since it was moving into the pulse of light. He saw the conductor at the back of the train start his watch first and begin to walk forward on the moving train. The light pulse then caught up to the forward moving front of the train. The conductor in the front of the train then started his watch. The final picture must remain consistent with the outcome of both conductors' experience on the moving train. Therefore, when the conductor from the rear of the train reached the front of the train, both watches showed the exact same time. The stationary observer at the side of the track saw that time for the faster moving conductor, who walked from the back of the train to the front, was slower.

In the years following, until confirming evidence in 1919, Albert Einstein added to his theory by examining the cosmos as a four-dimensional system of space-time in terms of accelerating frames of reference. He allowed nature itself to choose the mathematical coordinate system rather than the scientist forcing nature into his mathematical model. The theory of general relativity eliminated the need for a force of gravity to explain the acceleration of falling bodies or accelerating planets. Problems always existed with

gravity. Newton, even from the start, had trouble with a "force at a distance." Instead, Einstein claimed that all free falling objects followed the geodesics of curved space-time. Space-time was a field, like a magnetic field, subject to change by the presence of matter. Whether or not space-time was made of a substance such as aether became irrelevant. In field theory even empty space could be altered in its nothingness. The presence of the mass of the sun changed the four dimensions of space-time to permit the planets to move as they do. The field could change by the influence from the mass which was the source of gravitational changes distributed throughout the field.

Much of the detailed explanations is hidden from the novice in the mathematics. However, some relativistic phenomena can be seen. In 1919, during a solar eclipse, a star was observed that according to straight line space of Newtonian physics should have been behind the sun (FIGURE 22.1). The sun's massive presence impressed change on the surrounding time and space as predicted by general relativity according to Albert Einstein. Such bending of electromagnetic waves by gravitational fields was also demonstrated by controlled means. In 1971 radar echoes were bounced off of the surface of Venus as its orbit took it behind the rim of the sun. Non-Newtonian delays in time for radio signals from the artificial satellite, Mariner 9, were recorded in 1972 and 1973 while the satellite orbited Mars.

Accurate measurements of the orbit of Mercury showed that the orbit is not an ellipse. The position of the perihelion of Mercury also orbits the sun making the actual path that Mercury follows a spiral. This spiral orbit, which could not be explained by the laws of planetary motion according to Kepler or the laws of motion and gravity according to Newton, confirms Einstein's general relativity.

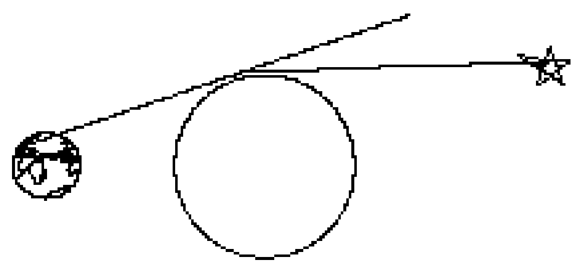

FIGURE 22.1 THE RELATIVISTIC BENDING OF LIGHT BY THE PRESENCE OF MATTER.

It is on the inside of the atom where relativity provides the most successful explanation. Many subatomic particles were found by accelerating those particles in electromagnetic fields. As the particles increased their speed, their masses increased and their times slowed down permitting easier detection. In fact, today the presence of a high concentration of mass of the atom in the nucleus and the low mass of electrons surrounding the nucleus is in part attributed to the high speed of the particles that make up the protons and neutrons compared with the slower speeds of the electrons. Thus, kinetic energy becomes equivalent to mass which is Einstein's famous equation E = m(c squared). Also, within the nucleus of the atom, physicists describe particles that are continually being created and destroyed, fading in and out of existence as matter passing in and out of an energy form according to E = m(c squared). In a sense, matter is no longer thought to exist, only degrees of compacted energy, and if all moving subatomic particles were to come to rest, they would cease to display the property of mass and thereby cease to be.

A "thought experiment" showing that energy can be transformed into mass begins with a light bulb at rest surrounded with a field, most of which lies to the right of the light bulb. At an initiating moment, the light bulb flashes on and off. The light pulse, a quantity of energy, moves radially outward and strikes the left limit of the field where the light is

absorbed. The law of conservation of momentum requires the impact of the light to cause the field to move leftward, the light bulb to remain stationary within the field, and the light pulse moving rightward to continue. Eventually the rightward light pulse impacts on the limits of the field in that direction. Again, conservation of momentum requires such an impact on the right limits of the field to bring the entire field, which was moving leftward, to rest. But then the law of conservation of mass-energy requires the existence of that energy to remain. It does, in fact, remain as entropy, a form of heat in which the molecules or plasma particles are moving faster throughout the field wherever the light energy was absorbed. The particles moving faster according to relativity then had more mass. The light energy therefore was converted into mass confirming in this "thought experiment" that E = m(c squared).

2. QUANTUM PHYSICS--MAX PLANCK AND ALBERT EINSTEIN

The electro-magnetic waves of James Clerk Maxwell had been so successful at the end of the nineteenth century and the technological gains were so miraculous with the invention of wireless communication leading to radio broadcasting in every home in the western world, that few of the people using radios ever knew that the laws on which their entertaining gadgets rested were wrong. On the technological side of research, a great interest had developed in searching for more and more efficient metallic filaments for the manufacture of better electric light bulbs. It was well known that the hotter a metallic filament became, the shorter the wave length of light that the filament gave off, first long dark red then shorter orange wave lengths. An ideal radiator, a substance that gave off energy waves dependent only on temperature, was called a black body. Such a substance usually was black when it was cold. As the temperature of the substance increased, the wave length of energy given off became shorter; the shorter the wave length, the higher the energy. Max Planck (1858-1947) took an interest in such metallic filaments and tried to show the conservation of energy between heat energy and light energy.

Energy was known to be continuous meaning that an infinite number of wave lengths existed; a continuous spectrum of colors existed. As filaments were designed to withstand hotter and hotter temperatures, it was found that a spread of wave lengths occurred with the hotter temperatures. A continuous and broadening spectrum occurred as the temperature of the filament increased. A glowing red filament went to orange, but then not to yellow or green. Instead, the filaments would become glowing white and finally bluish containing all colors and many ultraviolet wavelengths. If the spectrum of energy was truly continuous and energy was dependent on the wave length which then was seen to be spreading out into all wavelengths, then an infinite amount of energy would be emitted as the temperature rose and pushed the color spectrum into the ultraviolet region. This impossible result was called the ultraviolet catastrophe and caused the collapse of the "certain" laws of science concerned with the wave model of light and the laws of thermodynamics.

Responding to the ultraviolet catastrophe, Max Planck, in 1900, published his idea on the quantum theory of energy which stated that energy was not continuous, but was transmitted in small bundles. These bundles of energy left gaps in the spectrum and required a probability view of the laws of thermodynamics. Together with Einstein, Max Planck developed mathematics that took wave lengths of a form of light and converted such wave lengths into photons, weightless particles. Oddly, even though Maxwell's wave descriptions of energy had failed, some notation of waves remained. The twentieth century scientist sees light as displaying both particle and wave properties at the same time. They refuse to try to resolve the seeming contradiction.

Niels Bohr (1885-1962) coupled quantum energy theory with the planetary view of the atom with its nucleus being orbited by electrons. In 1913 he explained the simplest atom, the hydrogen atom with one proton and one electron, as a planetary system that had many orbits at different levels around the nucleus (the proton in the case of elemental hydrogen). When an electron received a quantum of energy, it would leap to the next quantum level for its orbit. If the electron lost energy by falling from one energy level's orbit down to a lower energy level of a different orbit, that quantum energy was released as a photon giving off a distinct single color. In a vial of hydrogen gas every possibility of quantum energy levels would be represented in the quintillions of atoms present. Each single electron orbits its proton at its own individual quantum level. The energies from hydrogen gas through which a high voltage of electricity passed would produce the discontinuous line spectrum. Hydrogen gas would show one red line, one green line, and two blue lines in the visible spectrum (FIGURE 22.2, Balmer Series). Niels Bohr had solved a riddle in nature by explaining the discontinuous spectrum. It was Planck's quantum energy theory that provided the answer. It was confirmed that energy existed in photon bundles.

The new paradigm for energy was quickly used in a long list of applications. We will examine only one. Recall Aristotle's explanation of the rainbow as a reflection of the sun with each color ring being the sun's reflection seen farther away. Grosseteste's view explained the rainbow by refraction of light in a raindrop and a reflection against the background of clouds. Theodoric of Freiberg kept the entire phenomenon within the droplet of rain and claimed that white sun light refracted into the spectrum of colors on entrance into the droplet and then internally reflected on the back of the droplet. Quantum energy, accepted by the scientific community of today, gives an explanation and dismisses any optical explanation as being only superficial. The quantum energy explanation begins with white light entering the skin of the raindrop. Energy, trapped in a circular path, whirls around the droplet until certain quantum rotary momentum levels are reached. The quantum energy bursts out of the droplet at two chief quantum angles of 42 degrees and 50 degrees showing forth the spectrum of colors in the rainbow. A large mixed quantity of energy fills the inside of the primary bow and a dark band shows a region of energy absorption just outside of the primary bow. These bright and dark regions of space associated with a rainbow never could be explained by pure optics. Again old laws of optics failed.

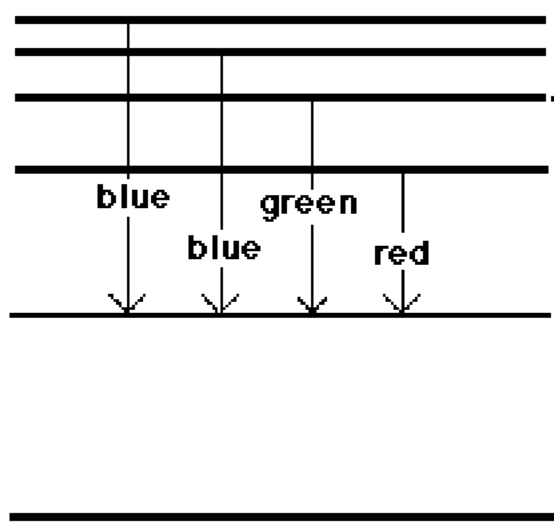

FIGURE 22.2 THE BALMER SERIES OF VISIBLE LIGHT EMISSIONS FROM ELECTRONS FALLING TO LOWER QUANTUM ENERGY LEVELS OF HYDROGEN ATOMS.

3. THE COMPLETION OF THE EXPLORATION OF THE EARTH

By 1900, the hope of the great exploring age had been abandoned. It had started systematically with Prince Henry the Navigator and a frenzied pace was set after the first voyage of Christopher Columbus to find the great southern polar continent thought to be rich and populated as suggested by Ptolemy and also to find the northwest passage. Charles Wilkes had contributed to the discovery of more than 1200 miles of Antarctic coast line which showed the seventh continent to be an uninhabitable barren wasteland. The search for the northwest passage led to the discovery of the Canadian Archipelago and the belief that the Arctic was also a useless, impenetrable frozen sea.

It took the special interest of Fridtjof Nansen (1861-1930), a Norwegian scientist and professor of zoology at the University of Christiania, to give the world renewed interest in the polar regions. On August 16, 1888, Nansen led five other men with teams of dogs pulling sleds from Kjoge Bay on the east coast of Greenland. They proceeded over the great ice sheet reaching an altitude of 8920 feet above sea level and then descended to the west coast coming off the ice cap at Ameralik Fjord on September 5, 1888. This was the first crossing of the desolate ice cap of Greenland and paved the way for the great heroic explorations of the twentieth century.

At the direction and according to the design of Nansen, Norway built a special polar research ship FRAM with an exceptionally strengthened hull pointed at both the bow and the stern, with the sides tapered, calculated to receive and deflect the crushing blows from the sea ice. Nansen's hope was that even if the wind would trap the FRAM into an inescapable region of the frozen sea, the ice would then lift the FRAM out of the sea rather than crush it. The FRAM, commanded by Capt. Otto Sverdup, sailed north on June of 1893 taking an expedition led by Nansen to the permanent pack ice of the Arctic Ocean north of the Nordenskioll Sea. According to Nansen's plan, the FRAM was forcibly driven into the pack ice and frozen in place for thirty-six full months (September, 1893 to August, 1896). It was a dramatic demonstration by Nansen which showed the scientific community that the frozen Arctic Ocean was not static. The ice-locked ship moved with the moving pack ice circumnavigating the North Pole. The FRAM, in fact, did not circle the pole, but during its three years of drifting at the locked-in guidance of the ice, it traveled in an arc of 900 miles and was freed as the pack ice broke up east of Greenland. The distance drifted by the FRAM was more than enough to show that the Arctic Ocean ice was actually moving clockwise around the North Pole.

Authors of previous science textbooks on physical geography and oceanography had claimed with certainty that the Arctic Ocean was shallow, filled with many islands, and frozen without a current. This Norwegian polar expedition showed the slow circular motion of the ice pack and also observed that the water under the ice pack had a current independent of the wind above the ice. Soundings of the ocean revealed a deep ocean basin, deepening poleward, with no islands. Under the ice pack was discovered warmer water of +1.0 degrees C with a high salt content, also not expected by the known laws of oceanography. Dr. Nansen and Lieut. Johansen attempted to reach the North Pole by dog sled, but found the hummocked pack ice too difficult to traverse. They did reach 86 degrees 14 minutes of arc North Latitude before turning back. They managed to reach Franz Joseph Land to winter in reasonable safety and were rescued by the WINDWARD which took them back to Norway.

Through courage, sacrifice, and devotion, the men of these bold expeditions showed how to penetrate deep into the unknown, and cross desolate barriers to reach the still unexplored regions of the earth. The expeditions of Nansen also showed that much concerning the fundamental principles of science could be learned in these desolate

regions. For example, the spin of the earth on its axis could be detected by the influence of a coriolis force on Arctic Ocean circulation.

Lt. Adrien de Gerlache on the Belgian ship BELGICA sailed south from Tierra del Fuego in 1898 to discover the strait between the Palmer Peninsula of Antarctica and the islands of Anverse and Brabant. Several landings were made to collect grasses, mosses, lichens, and algae. Observations of bird life were also made before the Belgian expedition became locked in the pack ice of the Bellingshausen Sea. They drifted with the ice more than a year counterclockwise around Antarctica below 70 degrees South Latitude for six hundred miles. This was the first scientific expedition to winter-over in the Antarctic and provided the first year-round meteorological observations south of the Antarctic Circle.

A British scientific expedition in the Antarctic led by C. E. Borchgrevink from 1898 to 1900 was sent south for magnetic and meteorological observations. The studies of marine and terrestrial life they did showed the surprising results that the coastal waters of the Antarctic could support a high population of animal life, a view not believed before. This scientific investigation was just the start of the exploration of the last continent. When it came to systematic scientific explanation, in the tradition started by Capt. Cook, the British led the way. A National Antarctic Expedition of Great Britain from 1901 to 1904 was the largest expedition up until that time at the start of the twentieth century. It was led by Capt. Robert Falcon Scott from the H.M.S. DISCOVERY. He charted the ever-changing Ross Ice Shelf accurately measuring its cliffs of ice rising out of the sea which varied in height from seventy to two hundred eighty feet. The depth of the sea below, at the ice shelf's edge, was nearly four hundred fathoms. From the vantage point of eight hundred feet above the ice shelf in an ascending tethered balloon, Scott saw no end to the southward extent of the Ross Ice Shelf. Scott's expedition wintered-over at Hut Point. By overland treks using some dog teams, but mostly by relying on man-hauling sledges, Scott explored the interior of the Ross Ice Shelf and penetrated poleward to 82 degrees 17 minutes of arc South Latitude. A second party climbed Ferrar Glacier, crossed the Trans Antarctic Mountains, and became the first men to reach the high polar plateau of Victoria Land at an altitude of more than 8000 feet.

Between 1900 and 1910, Sweden, Scotland, France, Argentina, and Britain sent government sponsored expeditions to the Antarctic. The British Antarctic Expedition of 1907-1909, led by Lt. Ernest Shackleton from the H.M.S. NIMROD, sent three overland field parties to accomplish extensive surveying for mapping the last continent. Shackleton, with one field party, attempted to reach the South Pole. However, severe cold and the oncoming winter forced them to turn back at 88 degrees 23 minutes of arc South Latitude. A second field party explored the mountainous region near the Ferrar Glacier while the third field party led by T.W. Edgeworth David became the first to ever reach the South Magnetic Pole, then at 72 degrees 25 minutes of arc South Latitude and 155 degrees 16 minutes of arc East Longitude.

In 1910 three nations, Great Britain, Japan, and Norway, set out to reach the South Pole. Capt. Robert Falcon Scott, Lt. Choku Shirase, and Prof. Roald Amundsen were the respective leaders of these nations' expeditions. The race to the South Pole is a modern legend. The Japanese were thwarted by massive pack ice which extracted most of their energy in the effort to reach the coast of Antarctica and had to be satisfied with coastal exploration. They discovered Kainin Bay at the eastern end of the Ross Ice Shelf and explored the coast for one hundred and twenty miles. Scott, relying on horses whose legs failed miserably in the deep snow and on man-hauling, reached the South Pole only to see the Norwegian Flag and tracks of the energetic dog teams. Amundsen's team had planted the Norwegian Flag exactly at the South Pole on December 14, 1911. Scott's party of five, devastated in the defeat of being second and exhausted from man-hauling

their supply sleds, all froze to death on the return trip.

For the sake of scientific advancement, Scott's expedition was unparalleled. Continual magnetic observations were made showing the magnetic drift when compared to previous expeditions to Antarctica. Fossils associated with coal beds were found indicating a very different climate once existed in the present coldest and driest desert on earth. Continuous recording weather instruments were introduced into the Antarctic for the first time, and weather balloon soundings gave temperature and wind data to an altitude of 25,000 feet. Rock specimens from several places in the Trans-Antarctic Mountains, including thirty-five pounds of rock dragged back by the dying party, aided in putting together the global puzzles of continental formation.

The Australasian Antarctic Expedition led by Sir Douglas Mawson, in the field at the same time as Amundsen, Shirase, and Scott, made perhaps the most successful discoveries and brought back data for later interpretation which gave new global views of nature (FIGURE 22.3). Fifteen hundred miles of coastline of Wilkes Land was accurately mapped from a ship. The Australian ship sailed right through the mountains pictured on the maps prepared from Wilkes' data and Mawson too hastily showed contempt for the American sailor who first explored this coast line. Today, the physics of refracted light over the extremely cold ice cap of the high polar plateau is known to bend light far over the horizon which permitted Wilkes to see mountain ranges as much as a hundred miles off from their actual position. Scott's journals reveal a similar contempt for the land sightings made by the earlier British explorer, Capt. James Clark Ross. With a correction for the refraction of light, the awesome rise of the high polar plateau from the sea and the buried mountain ranges sighted by Wilkes which confirmed Antarctica's existence were very correct.

The Australians sent out five exploring parties from Cape Denison. One party attempted to reach the magnetic pole from the west, the opposite direction from which the British traversed. The multiple measurements of magnetic changes were used to trace the movements of the magnetic pole and its field strength. These interpretations in turn confirmed the belief that the interior of the earth was a molten liquid and moving differently than the solid crust of the earth. Three parties mapped different sections along the coast. Mawson with the fifth party explored inland across Mertz and Ninnis Glaciers, which bear the names of his two companions who died on that earlier march to the magnetic pole.

As winter descended on Cape Denison, the temperature of the air over the high interior polar plateau of Antarctica plunged to unknown levels with the end of sunshine during the long polar night. The resulting cold heavy air began to accelerate down slope and blasted out to sea over Cape Denison. Steady, nearly unceasing hurricane-force winds from the south came as a sudden shock. Mawson recorded this in THE HOME OF THE BLIZZARD.

"Wind alone would not have been so bad; drift snow accompanied it in overwhelming amount. In the autumn overcast weather with heavy falls of snow prevailed, with the result that the air for several months was seldom free from drift. Indeed, during that time, there were not many days when objects a hundred yards away could be seen distinctly. Whatever else happened, the wind never abated, and so, even when the snow had ceased falling and the sky was clear, the drift continued until all the loose accumulations on the hinterland, for hundreds of miles back, had been swept out to sea. Day after day deluges of drift streamed past the Hut, at times so dense as to obscure objects three feet away, until it seemed as if the atmosphere were almost solid snow."

"Picture drift so dense that daylight comes through dully, though, maybe, the sun shines

in a cloudless sky; the drift is hurled, screaming through space at a hundred miles an hour, and the temperature is below zero, Fahrenheit. You have then the bare, rough facts concerning the worst blizzards of Adelie Land. The actual experience of them is another thing."

"Shroud the infuriated elements in the darkness of a polar night, and the blizzard is presented in a severer aspect. A plunge into the writhing storm-whirl stamps upon the senses an indelible and awful impression seldom squalled in the whole gamut of natural experience. The world a void, grisly, fierce and appalling. We stumble and struggle through the Stygian gloom; the merciless blast--an incubus of vengeance--stabs, buffets and freezes; the stinging drift blinds and chokes. In a ruthless grip we realize that we are"

"poor windlestraws
On the great, sullen, roaring pool of Time."

"It may well be imagined that none of us went out on these occasions for the pleasure of it. The scientific work required all too frequent journeys to the instruments at a distance from the Hut, and, in addition, supplies of the ice and stores had to be brought in, while the dogs needed constant attention." (Mawson, THE HOME OF THE BLIZZARD, pages 119-120)

These down sloping winds made by sinking polar air were immediately seen as the trigger for weather changes which were hemispherical in scope. Sudden rapid spreading out of these katabatic winds from the central regions of Greenland and Antarctica would cause outbreaks of polar air masses to invade warmer regions equatorward in both hemispheres. A global understanding of weather could be achieved by understanding and monitoring polar winds. Diagrams of rising air in the tropics and sinking air at the poles resulting in prevailing wind bands of the earth were placed in every geography and science book concerned with global weather patterns (FIGURE 22.3).

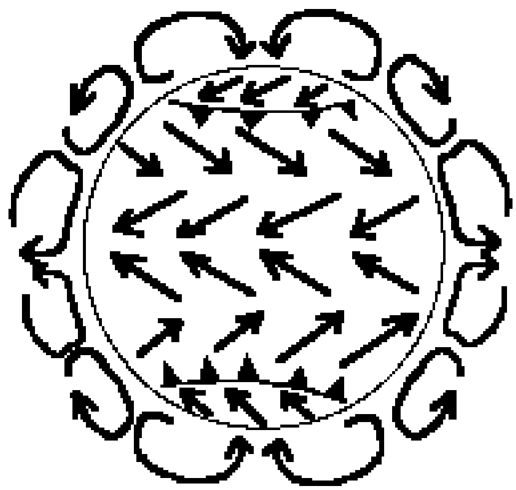

FIGURE 22.3 A CELLULAR MODEL OF GLOBAL ATMOSPHERIC WIND CIRCULATION SHOWING SINKING POLAR AIR AND THE RESULTING POLAR FRONT DRIVEN BY HEAVY COLD AIR AS THE DOMINANT FORCE IN THE ATMOSPHERE.

4. STIMULANTS FOR NEW SCIENCES

Archduke Francis Ferdinand of Austria, heir to the throne, and his wife were visiting Sarajevo, the capital city of Bosnia, which was a province annexed by Austria-Hungary

from the old Turkish (Muslim) Empire. On Sunday, June 28, 1914, on St. Vitus' Day, a Serbian national holiday celebrated by many Serbian people living in Bosnia under hated Austrian rule, a Serbian terrorist shot and killed the Austrian royalty. The assassin and his weapons were immediately traced to Serbia. One month later on July 28, 1914, Austria-Hungary declared war on Serbia. By the end of August, all of Europe was marching with massive armies using mass produced weapons to vent out massive casualties which numbered thirty-seven million before the eleventh hour of the eleventh day of the eleventh month in 1918. The brutal world war settled into a stagnant war separating the Central Powers from the Allied Powers by two fronts.

In Norway, the country of Nansen and Amundsen, Vilhelm Bjerknes with his son Jakob established the Bergen School of Meteorology in 1919 and developed a model of an idealized cyclone. This large scale low pressure system with cold fronts, warm fronts, and stationary fronts showed cold driven polar air masses clashing with less dynamic or even stagnant tropical air masses (J. Bjerknes and H. Solberg, "Meteorological Conditions for the Formation of Rain," GEOFYSISKE PUBLIKASJONER, Vol. 2, No. 3, 1921).

After the Armistice, Fridtjof Nansen became Commissioner of the League of Nations and worked for the repatriation of a half a million prisoners of war held in all parts of the world. He directed relief work through the International Red Cross of forty-eight countries to provide relief for 1,600,000 famine stricken Russians on the Volga River. He also was very influential in obtaining assistance from the United States in order to feed an additional 10,000,000 Russian sufferers. He worked for the protection and resettlement of Armenian and Greek refugees. In 1923 Nansen was awarded the Nobel Peace Prize which he donated to the revitalization of Russian agriculture.

The First World War brought basic research to an abrupt halt. Many promising young scientists gave their lives for their country. The sciences which were not immediately applicable to weaponry were abandoned until after the war. Immediately after the war scientists of the several nations which had tried to annihilate each other met together, as alumni might gather at a homecoming football game, to observe the eclipse of the sun and witness a star. This star should not have been seen save for the relativistic effects of gravity bending the light (FIGURE 22.1). Einstein's theory of relativity was thus confirmed. But trouble was occurring with Niels Bohr's planetary model of the atom. If electrons were solid particles carrying an electric charge and revolving around the nucleus, it was reasoned that such a circular path for electricity would produce a magnetic field. The electromagnetic oscillations around the nucleus would continually produce light, but everything we see does not glow in the dark. Again a beautiful picture of the structure of matter, painted by the theoretical scientist, failed.

The human signature impressed on nature can clearly be seen in the new atom proposed by the German scientists after the war. Before the war, men of science believed without a doubt that they had all the answers providing causes for all the effects in nature. Yet in their daily lives, seemingly without reason, their world collapsed in the flames of a global war. Worse yet, from the human rational perspective, the scientists were amazed that responsible men in the public sector demanded retribution and needed a loser for a war with no winners. When Germany was compelled to collect taxes from their own people to pay back Europe for the loses of the war, certainly seeds of the next war were sown, but a different science was spawned as well.

Erwin Schroedinger and Werner Heisenberg turned their scientific explanations into theories of chance and probability, without reason or preconceived design. According to Schroedinger, the electron was a bundle of energy compressed by forces which were produced by oscillating disturbances as energy converted back and forth between

potential and kinetic forms. The electron thus had both particle-mass properties as well as wave properties similar to light. The electron followed no knowable path so orbits did not exist. However, the electrons occupied regions of four dimensional space and time according to probabilities which Schroedinger called orbitals. The simplest orbital was a sphere centered on the nucleus called an s-orbital. The s-orbital was a region of space in which, for a time, an electron most probably existed. Because of the electrons fading in and out of existence, a person could never say in fact that an electron existed in the s-orbital sphere, but only that it probably existed there.

Other wilder looking regions of probability with more energy were developed. A p-orbital looked something like two sausages twisted apart at the nucleus. Three such p-orbitals existed with each sausage pair formed along each of the three axes of space. Four different d-orbitals displayed groups of four lobes for each orbital which stretched out from the nucleus. A fifth d-orbital, with two lobes pinched to a point at the nucleus, had a donut-like ring centered on the nucleus with the two lobes passing through the donut hole. Even more complex with more energy were the f-orbitals and g-orbitals. Never more than two electrons existed in a given orbital regardless of the number of lobes or seemingly distinct parts an orbital might appear to have.

Schroedinger sought no reason for these probabilities except chance. Probability rather than certainty governed the electron. One could not say what the electron did, other than that it probably existed in a given orbital of a probable quantum of energy. Light was emitted when the probability of electrons existing in a high energy orbital changed to a low energy orbital. Since many of the orbital regions of space overlapped, the physical presence of the electron did not have to change, only the orbital shape. All the while, such determination had to remain due to probability and chance.

Probability and chance were not just stepping stones as Einstein originally used them in the initial years of quantum energy development. Probability and chance were the best that could ever possibly be known, and they were formulated by Werner Heisenberg. In the very process of trying to understand the atom, Heisenberg mathematically showed that the atom was changed in that process. Heisenberg developed exacting mathematical expressions which today are known as the uncertainty principle. If we know the momentum of the electron, we cannot know the position of the electron. In order to measure the energy of an electron with perfect precision it would take an infinite amount of time. Since Heisenberg formulated these views, a complete spectrum of variations of these parameters has been developed. Knowledge of the momentum may be given up to achieve a narrowing in on the electron's position. Precision measurement of energy might be sacrificed in order to use a realistic amount of time to get the measurement.

Heisenberg's principle of uncertainty showed the limits that scientific knowledge can have and that science cannot understand things better. The principle of uncertainty required that all atomic understanding had to remain cloaked in uncertainty. It was not just a matter of waiting until human knowledge would grow to newer levels. Understanding of the substructure of the atom could only exist in a probabilistic sense and only in a random sense without a necessitating cause.

Einstein objected. He tried to preserve the thought that nature had design and order and that it might be man who has the limits. After World War I such ideas of purpose were rolled over with the same demolition as an advancing tank. Isolated and rejected, Albert Einstein answered for the record:

" . . . that in the long, it should be possible to frame one great field theory in which the traditional concept of causality would re-emerge. . . . I differ decisively in my opinion about

the fundamentals of the physics from nearly all my contemporaries, and therefore I cannot allow myself to act as a spokesman for the theoretical physicist. In particular, I do not believe in the necessity for a statistical formulation of the laws. . . . I can, if the worst comes to the worst, still realize that God may have created a world in which there are no natural laws. In short, a chaos. But that there should be statistical laws with definite solutions, i.e., laws which compel God to throw the dice in each individual case, I find highly disagreeable."

The randomness of positions, motions, and energies of particles in the interior of the atom and the continual spectrum of size of waves from compressing energy into particles gave the atom its structure with awesome quantities of internal energies. Methods were developed whereby a large number of heavy unstable atoms of uranium were placed in a concentrated configuration which permitted escaping neutrons to smash and split other uranium atoms. The chain reaction emitting the hidden nuclear energy was held in control by interspersing graphite matter between the uranium material. This was done in secret by a research team led by Enrico Fermi on December 2, 1942 under the stands of Stagg Field at the University of Chicago. At a test site called "Trinity" on a desert beneath the hills of Jornada del Muerto in New Mexico at 5:30 A.M. July 16, 1945, J. Robert Oppenheimer directed the ignition of the first uncontrollable nuclear chain reaction, the atomic bomb. All personnel on the project, which was cloaked in the secrecy of wartime, saw the dawning sky turn into a brilliant flash brighter than the noon sun of the desert.

At the first explosion of an atomic bomb in New Mexico, Oppenheimer quoted from Hindu scriptures, "I am of death . . ." as "Trinity" was blasted into vapor leaving behind a crater laced with glass instead of sand. Where God had asked Job, "Have you ever given orders to the morning . . . ?" (Job 38:12, NIV), these men said yes. What is amazing in the development of the atomic bomb is the hypocritical attitude displayed by the scientists. They had loved the secret intrigue, the special high rank of importance they held on the secret research team, their shuttling by military transport all over the country for secret meetings, and the wining and dining at military expense. Suddenly, with so-called mental anguish, shock of shocks, many scientists felt betrayed that the military used the bomb on two enemy cities rather than invade the enemy's homeland with drafted soldiers who could not get scientific deferments. Some scientists recovered rather quickly from that betrayal, and shaking off their guilt, built the hydrogen bomb. They tested it on Eniwetok Island in the Pacific Ocean in 1949, just four years after the destruction of two Japanese cities, and eliminated the island. The designing of scientific elimination of populated cities had been perfected.

5. THE INTERNATIONAL GEOPHYSICAL YEAR

An amazing display of international cooperation occurred with the International Geophysical year (July 1, 1957 - Dec. 31, 1958) which was a period of time chosen for its high sun spot activity. The major aim of IGY was to increase knowledge and improve understanding of the earth and its rapid changes. In order to do that, a concentrated study of the sun and its changes was included also. Sixty-seven nations participated and promised to share all information and cooperate for several years thereafter in the analysis of the data collected. A global monitoring of both natural and man-made nuclear radiation led to a rapid agreement between the nuclear powers to cease nuclear testing in the atmosphere. The findings were that nuclear testing was simply too detrimental to the entire planet. The discovery of the importance of the ozone layer in protecting the earth from natural radiation and the fragile character of that layer from chemical destruction from pollution below it were discoveries from IGY data.

A global mapping of glaciers had never been done before IGY. Physical exploration of Greenland and an intense concentration on mapping Antarctica was begun. Seismic soundings of Antarctic ice showed a continental ice cap of more than a mile thickness which disproved previous beliefs from physics that ice thicker than 2000 feet would melt of its own weight. As an extension of IGY glacial studies in 1966, a 4511 foot ice core was recovered from Camp Century, Greenland, and in 1968 a 7100 foot ice core was recovered from Byrd Station in west Antarctica. Analysis of these ice cores showed seasonal precipitation amounts from the visible layers of the cores. It was claimed that isotopes of oxygen in the trapped air of glacial ice revealed the original temperature of the snow and provided a picture of past climate back several hundred thousand years. The amount of ice, as seen by these very deep cores, was a surprise. More than 95 % of the world's fresh water is locked up in these two frozen ice caps, and if melted, they would cause the oceans to rise as much as five hundred feet.

Studies of the oceans during IGY gave ocean floor maps, revealed the presence of the mid Atlantic ridge, and discovered major counter currents in the deep layers of the oceans. Large scale rapid changes were discovered in several of the major surface currents of the oceans such as the Gulf Stream. This opened an entirely new set of parameters for weather forecasting in the immediate coastal regions bordering the ocean currents and for longer term climate analysis and prediction. The interrelationship of air and sea became a new discipline of science when it was found that the ocean stored great quantities of energy and converted that energy for release as storms, winds, or sensible heat at different times and at different rates.

Gravity measurements taken around the globe simultaneously determined the shape of the earth more precisely. Rocket soundings of the ionosphere provided the beginning of an understanding of the ionic electrical storms which in turn improved global communications dependent on bouncing signals off layers of that region of the atmosphere. Magnetic studies on a global scale together with seismic studies improved knowledge of the interior of the earth. Seven layers were found beneath the earth's crust--four separate layers of the mantle, a liquid core, a transitional layer, and a solid inner core.

Rocket probes of the high atmosphere and near space between the earth and the sun were also part of IGY. Pioneer rocket probes sent to crash on the moon penetrated two very large radiation belts which were highly dangerous for future space travel. These belts were named after the project leader James A. Van Allen. Follow-up studies revealed a very complex magnetosphere of which the Van Allen belts were only a part. The Van Allen belts wobbled in a daily cycle. The plasmasphere between them rotated daily keeping up with the earth's rotation. The entire magnetic field toward the sun extended out into space about five earth radii, but then it was blasted by the solar wind. The other part of the magnetosphere was solar wind swept behind the earth several hundred earth radii forming a tail which always points away from the sun as the earth spins underneath it. The magnetosphere is open in two polar cusps down through the atmosphere, through which solar wind particles pour, creating aurora over the earth's geomagnetic poles. The energized atmosphere gives off fluorescent light due to the external energy from the plasma materials from the sun which we see as the Northern and Southern Lights.

The Soviet Union and the United States planned to launch satellites during IGY. Only the Soviet Union managed to meet the schedule, but satellites since then have provided magnificent gains for global studies of any phenomenon visible from space. The most successful non-military use of satellites has been for monitoring agriculture, finding usable land, and monitoring global weather patterns.

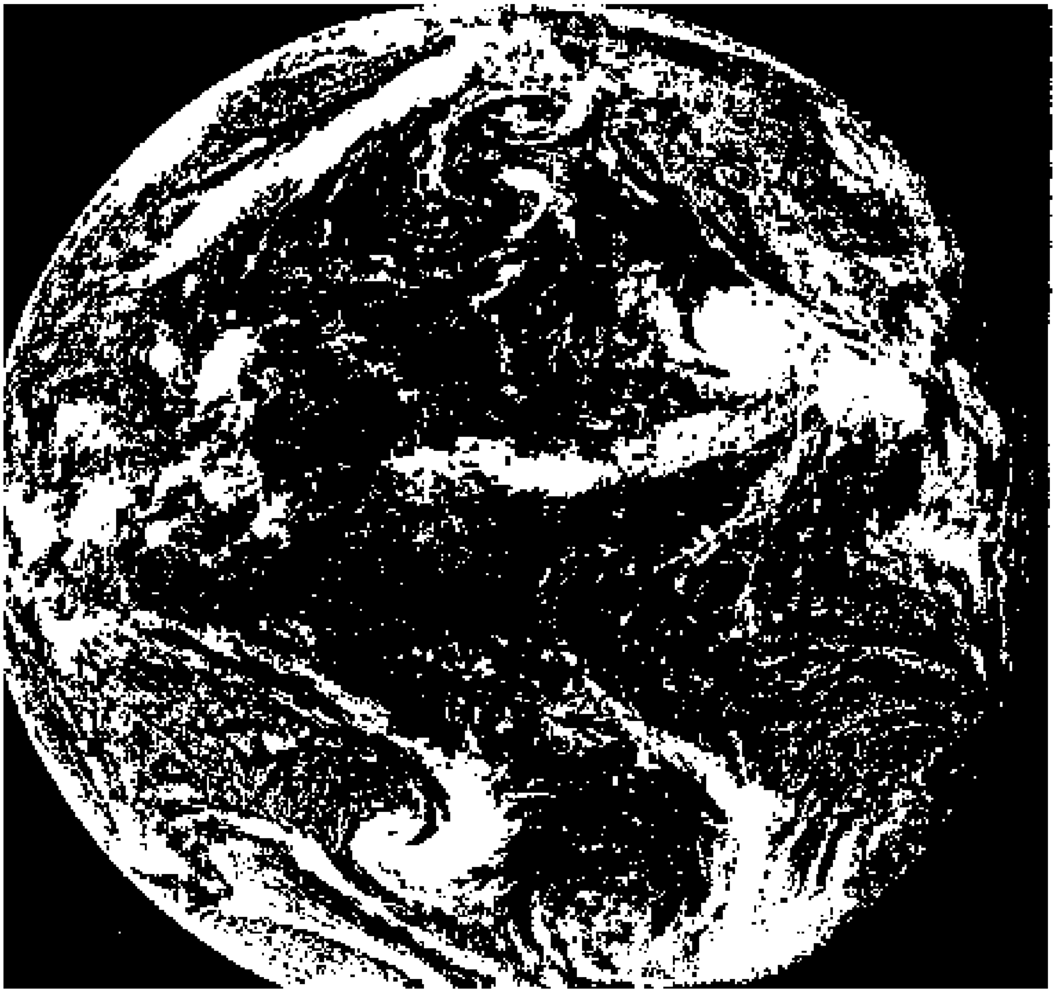

FIGURE 22.4 GOES-West VIS image, 2145 UTC, September 21, 1982. This satellite image shows the major storm systems previously unknown and untrackable before the satellite era.

(P. Krishna Rao, Susan J. Holmes, Ralph K. Anderson, Jay S. Winston, and Paul E. Lehr. WEATHER SATELLITES: SYSTEMS, DATA, AND ENVIRONMENTAL APPLICATIONS. Boston: American Meteorological Society, 1990, page 308; reproduced by permission.)

For the first time a complete weather picture could be received. The data from weather satellites were at first overwhelming. True progress could be made only after experience was gained in the rapidly changing digital computer technology and coupled with satellite data. The mathematical models of the atmosphere used to fill in the missing gaps of knowledge over the unobservable oceans were nearly abandoned because of the success of satellite observations. "Now-casting" instead of forecasting was used. Emphasis on just what the satellites saw seemed more successful than known laws of physics governing the atmosphere. With satellites, not only could clouds at every level over every part of the globe be seen (FIGURE 22.4, Rao, Holmes, Anderson, Winston, and Lehr, WEATHER SATELLITES: SYSTEMS, DATA, AND ENVIRONMENTAL APPLICATIONS, Boston: American Meteorological Society, 1990, page 308; reproduced by permission), but by making use of filters and refraction properties of the

air, global temperature distributions at multiple levels could be monitored. Water vapor could be traced in different levels to give exact wind patterns, and incoming and outgoing heat radiation for the earth's energy budget became available. The atmosphere was found to be so different that it took years to revise fundamental laws of global circulation. Frontal analysis of weather, filled with the jargon of World War I, became very inadequate. Mesoscale analysis which viewed single thunderstorm cells and their downbursts and gust fronts and fine structured wind shears were replacing the old inadequate methods. This work was pioneered by Theodore T. Fujita and popularized by Walter Lyons.

During IGY it was found that major weather systems, not expected to penetrate over the high ice cap, in fact, did so several times a year. With studies of the micro-weather changes by Paul Dalrymple during IGY and followed up by Heinz H. Lettau and Werner Schwerdtfeger, it was discovered that the surface winds of the interior of the Antarctic circled the ice cap, forming the katabatic winds only during times of heavy build-up of severely cold air, perhaps made unstable by an invasion of non-Antarctic weather. The Antarctic weather appeared not to be dominated by subsiding air from the high regions of the atmosphere, and the outward katabatic winds were not a global influence that controlled the world's weather. Satellites showed long wave radiation (planetary outflow of heat) from the Antarctic was at a low level. Data from stations on the surface of the ice cap also showed the Antarctic was not functioning as the earth's chief heat sink from which excess energy left the earth as previously believed.

These two problems, that the Antarctic ice sheet influenced the wind, but did not provide a factor for the dominance of the weather of the hemisphere, and second, that the passive energy release role of the polar region was not as large as expected, led to the realization that the polar regions did not influence global weather as once believed. Satellite views of an entire hemisphere at a time did not show prevailing wind belts but spirals of turbulence on a hemispherical scale which carried energy from the tropics. As science progresses toward the twenty-first century, the tropics are viewed as the region from which the world's weather comes. The complex structure of weather viewed from mesoscale meteorology coupled with satellite and radar data discredit the polar front theories of World War I. After all these advances, at this writing, something as basic as how a rain drop actually forms and grows large enough to fall remains a mystery. Yet another generation of scientists will seek after the Father of rain (Job 38:27).

6. CONTINENTAL DRIFT--SEA FLOOR SPREADING

In the science of weather analysis, change is expected, but the biggest change in scientific thought brought about by IGY occurred in the theories of the geological structure of continents. In the previous century Sir Charles Lyell initiated the idea of the development of continents and Charles Van Hise developed it to a mature state of science with his concept of the Precambrian Shield (the so-called oldest bedrock formations). These men saw the continents as fixed continents gradually enlarging after each ocean advance from ocean sediments which were always growing outward from the Precambrian Shield.

In 1912, struck with the way in which the east and west coastlines on both sides of the Atlantic Ocean appeared to fit together as puzzle pieces, Alfred Wegener proposed a continental drift theory. He provided no mechanism for such movement so he was never taken seriously. (He lost his life during an expedition to Greenland in 1930.) After the overwhelming data from IGY, the theory suddenly became acceptable. The establishment of Antarctica's coastlines and the determination of its mountain ranges played a major role in fitting the Southern Hemisphere continents together as Gondwana

Land. The rock structure of the Trans Antarctic Mountains matched the structure of the South American Andes and the Great Dividing Range of Australia. Finding fossil remains of a sheep size reptile known as Lystrosaurus in Africa, Antarctica, and India showed that their respective shores once had to have been together (FIGURE 22.5).

The discovery of the Mid Atlantic Ridge, with its crustal rocks pushing up wedges, provided the mechanism Wegener lacked. Satellite surveying demonstrated that the upward pushing wedges of the Mid Atlantic Ridge caused the sea floor of the Atlantic Ocean to spread by a rate of about four centimetres per year. These wedges were formed from magma ooze and as they solidified, crystals took on the magnetic orientation of the magnetic field of the earth. According to scientific interpretations, over 180 million years during which the Atlantic Ocean spread out from a crack between South America and Africa to its present width, the magnetic field of the earth reversed a number of times, and these reversals were left recorded in these mid Atlantic crustal wedges. On the other side of the world the same formations and magnetic shifts were discovered in the Pacific Ocean and in the Indian Ocean.

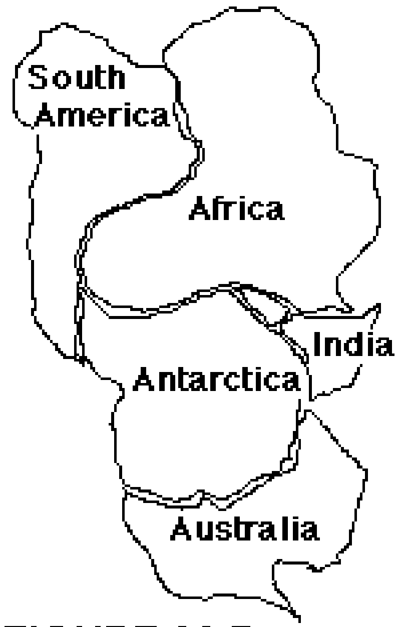

FIGURE 22.5
GONDWANALAND

The full picture was developed in the 1960s. Great plates of the earth's crust made of some of the sea floor and a continent are pushed apart from the subsurface ocean ridges by wedges rising from the mantle. On the opposite side of the plate, just off the coast of California for example, it crashes into another plate and is bent downward to sink and melt down in the mantle again. The entire process of rising out of the mantle, moving across the outer surface of the earth as an ocean floor or a continent, and sinking back into the magma was calculated to take 200 to 250 million years which immediately explained the absence of fossils before the mesozoic age even though the ocean basins had to be several billion years old.

7. QUARKS: "Three quarks for Muster Mark!" (James Joyce, FINNEGAN'S WAKE)

Between 1945 and 1965, every well developed country pursued the details of the nucleus of the atom. The awesome nuclear energies available from nuclear fission and fusion left hope for still more energies and mysteries in the structure of the nucleus. Nuclear piles with huge particle accelerators were built to send known particles at high speeds crashing into atoms and other particles in order to identify new particles. Over 300 sub atomic particles, some smaller and some larger than the proton or neutron were found. Muons, pi mesons, kay mesons, eta mesons, antiprotons, antineutrons, lambda baryons, sigma baryons, antisigma baryons, and antiomega baryons are just a few of such subatomic particles. But the number of subatomic particles became too clumsy. Physicists became suspicious. How could atoms be made of so many particles?

Murray Gell-Mann proposed in 1961 that the proton and neutron were made of still smaller particles, and what was being observed among the several hundred other particles was

really different combinations of the new particles or a spectrum of different masses for the same particles created from the large quantities of energy produced in the cyclotrons. Gell-Mann chose the name quark for the new family of particles. Quarks and antiquarks are readily created giving a balance of nothing and held together by energy to form mesons. Three quarks, two up quarks and one down quark, form a proton and three quarks, one up quark and two down quarks, form a neutron. A family of quarks, up, down, strange, charm, truth, and beauty seem to exist and have replaced most of the many other particles. Confirmation of the quark theory came in 1974 by Feynman's experiment which showed the electrical charge of a proton existed in a region five hundred times smaller than the proton itself. In 1979, finding electrical charges in multiples of 1/3 of the charge of an electron confirmed the charges of + 2/3 for up quarks and - 1/3 for down quarks. By crashing two high speed protons into each other in 1984, shredded quarks forming what was called a quark jet may lead to discovering still smaller particles.

8. ORDER FROM DNA

Among cells of life, one cell divides to produce two new cells. Thick strands of matter within that cell called chromosomes also divide. The chromosomes carry the many genes, each gene carrying a characteristic trait of the living organism of which the cell is a part. By this division the genetic traits of inheritance can be carried throughout the organism and eventually passed on to its offspring. In 1953 an American biologist, James Watson, and a British biophysicist, Francis Crick, at Cambridge University discovered the double helix structure of deoxyribonucleic acid, DNA. Within the double helix were pairs of bases built into a winding staircase structure. Watson and Crick showed that these bases held the genetic code among the millions of atoms within the DNA molecules. In cell division the double helix would dramatically unwind exposing the bases which then could rapidly be copied passing on the code as an inheritance.

Watson and Crick became for biology what Newton was for physics. Just as astronomy accepted for more than a century a heliocentric motion for the planets without physical cause until Newton's law of universal gravitation, now Mendel's peas and Darwin's changing species, which were also accepted for a century without physical cause, had a physical and mechanical reason in the changeable genetic code held by DNA. In the decades following there was miraculous progress toward the identification of individual genes with the promise of someday solving genetic defects. Transforming microorganisms is being done today in order to develop biological species with specific tasks such as attacking a specific plant disease or destroying a type of weed instead of using indiscriminating chemical insecticides or herbicides.

A Christian teacher could and should appeal to the wonderful and marvelous design God has given His living creatures. Yet what of DNA is absolutely true? Did not Christians of the past many times make the mistake of accepting ideas of people and mixing them with the truths of our Lord? The science of the market place, following the traditions of its Greek fathers, uses such a mechanism from the DNA molecular structure to show forcefully how natural processes occur by themselves and without the influence of a god. An argument from design in this twentieth century fails in the market place since a complex molecular structure such as DNA organizes itself and does not permit wholesale randomness. In this way the general philosophical view of evolution permits changes and at the same time does not permit many detrimental changes. Science has moved a long way from those Christian years with positive Scriptural influences. Men like Newton wanted desperately to be independent of religion and to be dependent on reason alone. Darwin found natural selection; Crick and Watson found DNA to be an atomic structure which operates like the atoms of Democritus, eternally without a spiritual cause.

9. A NOBEL PRIZE FOR THE NEW THERMODYNAMICS

A century past Mendelyeev's periodic view of atomic elements, which solidly confirmed the atomic theory for the structure of all matter, thermodynamics moved from a deterministic view of nature in which caloric fluid had to flow toward a run-down state of increased entropy to a statistical view embedded with probabilities and randomness. The old second law of thermodynamics, which claimed entropy, a measure of disorder, ALWAYS increased, was not true at all times. Ilya Prigogine, a physicist and chemist from Belgium, won a Nobel prize in chemistry in 1977 for his research on the organizational build-up of molecular structures during non-equilibrium states. He showed that entropy, a state of disorder, actually decreases during unstable conditions to which the normal laws of thermodynamics never could be applied. An application of Prigogine's new discovery about order coming out of chaos is the explanation of here-to-fore mysterious Benard cells, those cells of circulation which form distinctive patterns during rapid convective transport of heat through a shallow layer. In thin layers of fluid through which much heat passes, these Benard cells are formed so that the transport of energy may occur more rapidly (FIGURE 22.6, a sketch after Ernest M. Agee, "Observation from Space and Thermal Convection: A Historical Perspective," BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY, Vol. 65, No. 9, September, 1984, page 947). Such cells are commonly seen on the top of a hot cup of coffee or hot bowl of soup. Benard Cells have also dramatically been photographed from humanly occupied space craft over warm sections of the oceans or over thick cloud layers in the tropics. These large scale circulation patterns, as a result of Prigogine's research, now can be explained as the molecules organizing themselves, giving order out of chaos as large quantities of energy pass through the system in an unstable non-equilibrium state.

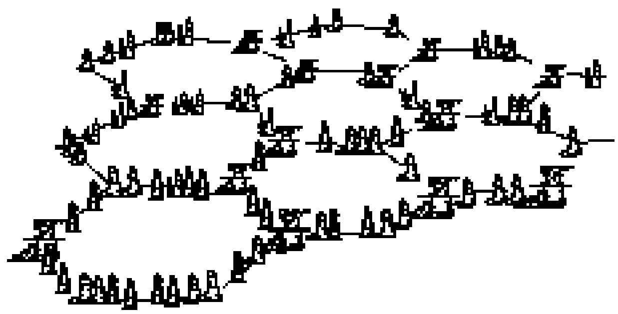

FIGURE 22.6 A SKETCH OF A TROPICAL REGION OF THE PACIFIC OCEAN SHOWING BERNARD CELLS, NEARLY HEXAGONAL REGIONS AROUND WHICH TOWERING CUMULUS CLOUDS GATHER. (After Ernest M.Agee, “Observation from Space and Thermal Convection: A Historical Perspective,” BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY, Vol. 65, No. 9, September, 1984, page 947)

Crick and Watson supplied the mechanical methods for the transfer of inherited characteristics from one organism to another and also a method for some change in the species. Prigogine with his corrected laws of thermodynamics showed how the energy is available for an improved order of evolution. Reason had achieved a molecular creation separate from His Word.

The changes in science this last century have been fast and furious. The attacks on Christian faith have been overwhelming. Christians may find the scientific age into which they have been placed too aggressive to confront with their own reason or strength. It is to the cross and the resurrection of Jesus Christ that we come in failure and humility.

"Oh Thou,
who changest not,
abide with me!"

(Luke 24:29, Lyte, Henry F. THE LUTHERAN HYMNAL. Hymn number 552, Concordia Publishing House. Reprinted by permission.)

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SEPARATE FROM HIS WORD

SCIENCE IS SEPARATE FROM HIS WORD: What then should we teach? The Concluding Chapter 23

Our study in the history of science has shown considerable changes in the human understanding of nature. We have seen science in western civilization begin with the ancient Greeks who attempted to explain changes of the natural world without the intervention of their gods. We have seen the early Christians reject the pagan view of nature because they knew that the Triune God in fact created all things in nature. We have seen the positive contribution to science that the knowledge of the Creator gave. We have also seen the rejection of such Christian beliefs in modern times, with the return to reason alone. With the atomic quantum view of matter and energy based on probability and chance and with an all encompassing philosophy of evolution explaining the physical and biological development of all things in the universe dominating science, then what should we teach in our Christian schools? When so much of science evades all religious views, what can we do?

1. TEACH ALL SCIENCE

We should teach all of science. We should especially teach science in its historical setting, for it is in history where we see science as it truly is. Through history we see science as a human activity trying to comprehend the wondrous natural world our Lord has placed us in. In its proper historical setting we can see all science, which includes the seemingly good science that can stimulate praise for our Lord as well as the seemingly offensive science which can threaten the Christian faith. Both views should be taught to the youngest children whom the teacher believes are capable of understanding the subject. When the children are young, God's Word remains supreme for them. Our Lord leads the children to trust His own Word over man's words.

The task of Christian teachers is most difficult when comparing their work to other teachers. The unbeliever, who teaches science, teaches only the accepted science of today. In fact, the vast majority of science textbooks are written with a hostile view of history. These textbooks generally claim the science of today is correct and true while the genius of the past, which also was once accepted as true, is ignored or ridiculed. The Christian teacher must teach the views of science commonly accepted by the practitioners of science of his age, but in the bright light of God's true Word. If some of the humanly formulated laws of science ignore our God who rules over all of nature, or even reject Him, the Christian teacher must teach that also without trying to fight science with more science. Our Lord alone knows His ordinances for nature which He has created and now maintains. The Christian teacher must also teach the historical development of science in order that the child might see correctly what happens to laws of science developed by the reason of people, many of whom have rejected God's ways.

In the child's educational development, he or she should learn of the first atomists so they know the original concept was that atoms move without influence or need of a god. The child should learn that atomic concepts were rejected because of the realization of how wondrously the human mind was created. The child should learn that when the new laws governing atomic matter were developed, evolution of life likewise strongly emerged. The child should know the role of probability and chance in atomic theory which denies direction from God; that is part of modern atomic science. The child should know when

protons were discovered as parts of the atom and quarks as parts of the proton and glueons as parts of the quarks, that the wisdom of human beings is acquired in an uncertain manner. Text books without history will not show this uncertainty. In this way, the humility of human knowledge can be taught, as well as an excitement for the next generation of which the child is a part. When all of the answers are not known, a door is left open for the child to make many more discoveries in God's unfathomable world.

The children should be taught how laws of science that are wrong can slow down human understanding. Recall that it was not until Christopher Columbus was bold enough to sail westward and find wind systems far out at sea and sea currents in the ocean, that ocean navigation was freed from the laws of science of Aristotle. One need not think too long to imagine how false laws of science may be holding back our age from knowledge available in nature today. Such concepts rightfully excite the child of God to look for the Lord's ordinances. Let the youth dream of new sources of energy, new laws of geology for finding new and more mineral resources, new biological classification systems which express God's hand in nature, and new cures for genetic defects.

The Christian child should be taught the horrors perpetuated against pagans in the name of Christianity. They are not chapters in our own history to be proud of, but they do show us and the children we teach that we must remain humble and that our Lord truly loves all people. It is especially important to lovingly pursue the unbelievers and show them their Savior. When Christians in the past abused, tortured, and killed the pagans for their unbelief, they were not listening to their Savior, but rather following their own reason which all too often was wrong.

The brightest chapters in the history of science are those in which Christian philosophy contributed much to the growth of science. It follows without saying that these should be emphasized. The Triune God, in fact, designed all things. God did, in fact, create all things. Our Lord, in fact, created all things with order. He, in fact, created all things with purpose. The search for such God-given order is a God-pleasing endeavor for a Christian to pursue. Our Lord has blessed such pursuits. The heavens have always declared His glory making the pursuit of the understanding of nature a most enjoyable occupation for many of God's children.

2. TEACH THAT NATURE AND SCIENCE ARE DIFFERENT

To a scientist, one of the most exciting traits of science is pursuing new ideas that can take the place of laws that failed. It is our humanity that leads to failures in science. It is the immensity of nature itself, so complex and beyond human understanding, that continues to lure the human mind to attempt to explain the natural world again and again. Failure following each explanation coupled at the same time with the belief that more can be understood after each failure offers the scientist the excitement of seeking still more observational evidence, even though it may be dangerous conditions, in the laboratory, under the sea, over glaciers, in the jungles, in outer space, and within the mind itself.

Scientific explanations always fall short. The proper positive pursuit of understanding, without arrogance or pride, can best be perceived through the history of science. Aristotle's gravitation and levitation explained motion more accurately than Galileo's accelerated motion apart from a vacuum. Much was learned from Aristotle's realistic methods. Much was learned from Galileo's idealistic methods. Neither set of laws could be counted historically as the very ordinances with which God governs nature. Newton's law of gravity was not God's law. Newton imagined the earth and the moon as points, which they were not. Much was gained using these laws as approximations of the unseen

ordinances of God which governed nature. Aether of space both solved problems with Newton's law of gravity as well as led to the rejection of the same law.

It is through human inadequacies of describing nature with science that we learn that theories, laws, and facts of science are of a human origin. Limits of human beings must be left as of humans and the wisdom of God must be accepted as of God. Light, created by God on the first day before He got fancy with the complex intricate order of each successive creation day, remains a mystery throughout all of history. The science of Aristotle saw light dependent on the eye power of each human being, fading to blackness at the personal limit of each individual. Newton's science demanded light be of a particle nature to move through his empty space which was required by his view of planetary motion. The weaving of fact, theory, and law continued with Maxwell's electromagnetic spectral wave structure of light, only to change once again into weightless particles called photons in the twentieth century. Oddly, in the history of science, weightlessness of particle substances usually leads to a rejection of the concept. Without knowledge of light, nothing perceived can be comprehended, and when the fundamental ideas about light change, everything in science changes. Such revolutions in science change the fundamental definitions. They change the interpretation of facts and even the identification of what is factual.

Science in the fourth century B. C. explained the rainbow as light emanating from our own eyes which was beamed outward to comprehend the sun's reflection at different distances. In the twelfth and thirteenth centuries, the rainbow was explained as a product of reflective and refractive optical processes. Then in the twentieth century the rainbow was explained as a series of quantum energy releases. God's Word, the only unchanging and true explanation and certainly true, explains the rainbow as our Lord's contractual signature in the sky giving His promise to all living creatures on earth that never again will the entire earth be destroyed by a flood. Science remains an attempt by human beings to explain the environment in which the almighty God has placed them. Science is not a synonym of nature.

3. TEACH THAT IDEAS OF THE PAST FAILED: WE CANNOT GO BACK

In these times, when so many of the laws and principles of science appear to show a natural world quite different than that described by Moses, a tendency exists to teach a kind of science as it was during those more comfortable centuries when Christian men of science dominated scientific thought. Science has changed from those times and in ways not always for the better. History reveals that sixteenth and seventeenth century science, though very powerful and successful, in time failed. Science as ideas of human beings is not and has never been synonymous with nature. In the market place where it is spawned, science of human beings has always been separate from His Word, even when well-intentioned Christians were in the forefront of its development. Christians in the scientific community have and do follow Baconian idols with respect to their interpretations of nature. Such errors are unavoidable.

We cannot go back to more comfortable laws of science. They failed. The unchanging atoms failed. Continuous matter and the corresponding five elements replaced them and then failed themselves. Dalton's new atoms for a time provided new hope for chemistry. Such indivisible particles failed and gave way to atoms of multiple subatomic particles. Definite deterministic laws of thermodynamics failed with the failure of caloric fluid. Statistical probabilities and chance must become part of science if the atoms of Mendelyeev's periodic chart are to be accepted in chemistry. The Christian teacher does not have to embrace these random and statistical laws as certain, for he or she knows

better than Einstein that "God does not play dice." Nevertheless, such ideas are, in fact, part of science. Here is where the teacher should let the history of science reveal the uncertain and changing character of science. Such change is the strength of science, and in time, when randomness and probability give way to new sciences, progress will be made. The Christian knows that the Scriptures cannot be broken, but science is not as certain. At the same time a Christian teacher can be too quick to judge. It is better to let science be science and let the market place struggle with its endless debate.

Unalterable species cannot be linked to the Bible. Linnaeus' classification system failed. Darwin's changing species by natural selection, by the survival of the fittest, was an honest attempt to explain a natural method in life processes where an older system of classification using fixed species had failed. The variety in God's creation simply was too overwhelming for older scientific thoughts. New classification systems must be invented if Darwin's views are to be rejected without returning to a system that failed.

Noahic flood waters rising over immovable mountains failed as a scientific explanation because of the lack of measurable quantities of water on the earth and because of the actual measurement of rising mountains during earthquakes. If theories of geology are to be based on the flood at the time of Noah, new theories must be invented. It is not God's revealed Word that failed. It is the scientific laws that failed, and given enough time, history will expose the errors.

Astronomy suffered because of over zealous churchmen who demanded that the heavens were changeless. When mountains on the moon eroded, when stars blew up, or when new unknown stars were seen for the first time, the old astronomy supported by the church failed, and those blindly following human ideas failed with the failure of scientific explanations.

Failure in science is not a negative attribute, but instead, the very positive approach toward discovery. It might be frustrating to an individual to face failure, but it is how scientific knowledge, particularly inductive knowledge progresses. The great polar researcher and statesman, Dr. Fridtjof Nansen, writing in his diary about the pursuit of science while on board the FRAM in the process of discovering the motion of the frozen Arctic Ocean wrote:

"We are oddly constructed machines. At one moment all resolution, at the next all doubt. . . . Today our intellect, our science, all our 'Leben und Treiben,' seem but a pitiful Philistinism, not worth a pipe of tobacco; tomorrow we throw ourselves heart and soul into these very researches, consumed with a burning thirst, to absorb everything into ourselves, longing to spy out fresh paths, and fretting impatiently at our inability to solve the problem fully and completely. Then down we sink again in disgust at the worthlessness of it all."

"It is nothing new to suffer from the fact that our knowledge can be but fragmentary, that we can never fathom what lies behind. But suppose, now, that we could reckon it out, that the inmost secret of it all lay as clear and plain to us as a rule-of-three sum, should we be any happier? Possibly just the reverse. Is it not in the struggle to attain knowledge that happiness consists?" (Nansen, FARTHEST NORTH)

4. TEACH THAT OUR CHRISTIAN BELIEFS ARE INSEPARABLE FROM THE NATURAL WORLD

Our only reason to exist as Christian teachers rests on the fact that our Christian religion,

founded on faith alone, is real. While science may be separate from His Word, the natural world created by God is most certainly in perfect harmony with His Word. All subjects in the realm of knowledge should be taught with testimony from the Scriptures. From the Holy Scriptures we learn God's intent for man and man's deliberate rejection of God's truth. A faithful interpretation of these great truthful beginnings was written in a book of doctrine by Roland Hoenecke, a faithful servant as a teacher of teachers.

"'Let us make man in our image. . . .' (Gen. 1:20, NIV) Amazing words! Few in number, uttered at the birth of time, they unfold God's purpose for all time, yea, for time and eternity."

"Small wonder! They are the Creator's first recorded words spoken of the crown of His creation. In contrast to all previous fiats, they attest the distinctiveness of the human being."

"The climax and culmination of the creative activity consisted of infinitely more than a let-there-be or let-the-earth-bring-forth. A divine consultation preceded it! A unique process characterized it!"

"Man's creation shows yet more distinctiveness. Wonder of wonders, man was made in the Image of God! Thus endowed, the crown of creation possessed the faculty of blissful association with his Maker. Intelligent communication with the Omniscient would guarantee uninterrupted, perfect happiness. Seeing the Holy One in His unclouded majesty would ensure fullness of joy."

"Terrestrial language could never do justice to the great things God intended for man. Even the sight of it by way of a 'poor reflection' and the knowledge of it only 'in part' thrills us through and through. It simply passes all human understanding. Truly, God is love!"

"No longer is the situation as it once was and as the loving Creator intended it to remain. One fatal step ruined all. Yielding to the old evil foe's presumptuous offer, our first parents immediately and completely lost their prized possession."

"Far-reaching and consequential was the outcome: '. . . just as sin entered the world through one man, and death through sin, and in this way death came to all men because all sinned. . . .' (Rom. 5:12,NIV) O sorrow dread! Fear supplanted trust in man's heart. Love gave way to enmity. Tears of sorrow replaced the laughter of joy. Death, rather than life, became man's lot and prospect."

"Fortunately, the Creator 'does not change.' (James 1:17) Wearied with man's ungratefulness, His goal for man remained unchanged."

"God's grace designed the way to save rebellious man. Grace prompted the Father to offer up His Son. The Creator was determined that the 'apple of His eye' regain 'God's image lost.'"

"Possessed by Christ and cloaked in God's Image, God's children well know the sole reason for their continued stay in this vale of tears; theirs is the privileged task, as instruments of God, to transform their fellow men also into bearers of the divine Image. What a powerful incentive for them 'to give attendance . . . to doctrine.' (I Timothy 4:13, AV) To the glory of God alone, but with a burning passion for those still without their God's Image and the blessedness it brings, those renewed in the divine Image 'take heed . . . unto doctrine,' (I Timothy 4:13, AV) yes, 'Labour in the word and doctrine.' (I Timothy 5:17, AV) 'With devotion they work while it is day "until we . . . become mature, attaining

the full measure of perfection found in Christ.' (Eph. 4:13, NIV)" (Roland Hoenecke, "IN OUR IMAGE": A Study of Christian Doctrine)

Through His Word a child may be taught the certainty of our Lord's creation. God's gift of reason permits mankind to understand that creation as well as to learn the correct realization of human limitations with respect to science. Historically we have seen that the Christian did not set out to improve, recreate, or present many contributions to science. In fact, the early Christians were quite hostile to pagan science. However, by remaining faithful to His Word, they knew God created order. In that context Robert Grosseteste could, as a faithful Christian, promote inductive reason and invent laboratory science. Roger Bacon could advance the sciences through the order of mathematical models. Martin Luther could promote every useful art. Harvey could discover the circulation of blood. Boyle could reject fire as an element which in turn created the new science of chemistry. Agassiz could see God's great plow in the glaciers, reject Darwin's changing species by natural selection, and develop a classification system for plants and animals that showed a created ascendance to the crown of creation. Einstein could reject randomness and probability as part of God's order. Through faithful adherence to God's Word, much can be gained in the human understanding of nature.

Such faithfulness must be maintained today in spite of much opposition. Just because efficient and final causes are no longer important to men of modern science, it does not mean God's causes are inactive. Just because atomic theory is in vogue with all of the randomness and chance brought with such laws, it does not mean things in nature happen at random or by chance without a God-directed purpose. If atomic views show that the predesign of a Creator is unnecessary by scientific reason, then what of it? All of the complexity in nature continues to show God's design.

Evolutionary philosophy, which pervades all of modern science, logically passes through eons of time without seeing a creation. Such thinking, for sinful man, is not new. The real beginning occurred just as God permitted Moses to record it in Genesis. A Christian teacher does not have to be a renowned authority on science with the ability to overcome every new threat human wisdom casts toward God's Word. We are not defenders of God's Word; His Word defends us. When it comes to the study of nature, the Christian teacher shows a child a faith in created order. Such a knowledge of nature will be of benefit to all young men and women in whatever occupation our Lord might lead His children, especially to the next generation of scientists.

"Where then does wisdom come from?"

"Where does understanding dwell?"

"God understands the way to it and he alone knows where it dwells, for he views the ends of the earth and sees everything under the heavens."

"When he established the force of the wind and measured out the waters, when he made a decree for the rain and a path for the thunderstorm, then he looked at wisdom and appraised it; he confirmed it and tested it."

"And he said to man, 'The fear of the Lord--that is wisdom, and to shun evil is understanding.'" (Job 28:20, 23-28, NIV)

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Becker, Siegbert W. THE FOOLISHNESS OF GOD. Milwaukee: Northwestern Publishing House, 1982.

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Feyerabend, Paul. AGAINST METHOD. New York: Schocken, 1978.

Feyerabend, Paul. SCIENCE IN A FREE SOCIETY. London: NLB, 1978

Hoenecke, Roland. "IN OUR IMAGE": A Study of Christian Doctrine. Unpublished Manuscript, DMLC Library.

Kuhn, Thomas S. THE STRUCTURE OF SCIENTIFIC REVOLUTIONS. Chicago: The University of Chicago Press, 1962.

Nansen, Fridtjof. FARTHEST NORTH. New York: Harper and Brothers Publishers, 1897.

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Sponholz, Martin P. "Science and the Truth of Nature." CENTENNIAL ESSAYS: Eleven Essays to Mark the Centennial of Dr. Martin Luther College. Edited by Richard E. Buss. New Ulm, Minnesota: DMLC Graphic Arts Department, 1984.

Sponholz, Martin P. "Two Towers: The Relationship Between Science and the Bible." A paper presented to the Minnesota District Pastoral Conference. St. John's Ev. Lutheran Church, Minneapolis, Minnesota, April 20, 1982. DMLC Library.

Wandersee, James H. "Can the History of Science Help Science Educators Anticipate Students' Misconceptions?" JOURNAL OF RESEARCH IN SCIENCE. Vol. 23 (1986), No. 7, pp. 581-597.

THE END

Dr. Martin Luther College
The Printshop

APPENDIX I. THE COURSE DISCRIPTION OF HISTORY OF SCIENCE TAUGHT AT DR. MARTIN LUTHER COLLEGE

DMLC
MATH-SCIENCE DIVISION

I. COURSE IDENTIFICATION

Science 7077, History of Science

II. COURSE OBJECTIVES

The major aim of this course is to provide an overview of scientific thoughts as they were developed, amended, and supplanted in their specific historical settings. Such a view permits the Christian teacher to see man's persistent weaknesses and failings and still stand in awe of our Lord's subtle maintenance of His creation.

The student will:

A. Survey the broad scope of the chronological development of scientific ideas from ancient times to the modern day;

B. Study the times and lives of several of the scientific giants in each period of history;

C. Repeat by reason, by demonstration, or by experiment, the major ideas in each age and see the validity of scientific thought in the age in question;

D. Concentrate on observational anomalies and theoretical challenges to accepted scientific ideas in order to understand the essential tension needed for amendments;

E. Identify processes of failure in scientific explanations of nature that lead to revolution in science;

F. Feel, through mankind's struggle in developing the changing laws of science, a hint of the subtleness of nature that our Lord has made.

III. COURSE CONTENT

A. Ancient Traditions Toward Science

1. Earliest science traditions of Egypt and Mesopotamia

2. The Ionians: Thales, Anaximander, Anaximenes, Cleostratus, Xenophanes, Hecateus, Anaxagoras

3. The Pythagoreans: geometry, astronomy, music, and

medicine

4. The Atomists: Leucippus and Democritus, views of mathematics, astronomy, and matter

5. Plato and the Academy: the theory of ideas, the role of mathematics, ideas of celestial motion, ideas of the structure of matter

B. Ancient Science as a Foundation to Modern Traditions

1. Aristotle: DE CAELO, METEOROLOGICA, PHYSICA, HISTORIA ANIMALIUM

2. Alexandrian Science: Euclid's mathematics, Aristarchus' astronomy and physics, Archimedes' mechanics, Eratosthenes' geography

3. Science under the Dominance of Rome: Lucretius as poet of Epicurean science, atoms and evolution of life, Pliny's NATURAL HISTORY, Seneca's NATURAL QUESTIONS, Galen's medicine

4. The earth and universe of Claudius Ptolemaeus: GEOGRAPHICAL OUTLINE, and ALMAGEST

C. Empirical Paradigms Find a New Science

1. Science held hostage by Islam: Arabic alchemy to chemistry, Jabir, Rhazes, Averroes

2. A view of paradigms for sublunar meteors from Grosseteste and Roger Bacon

3. The new geographers: Bartholomeu Dias and the cold south, Christopher Columbus as discoverer of the Trade Winds, James Cook and Charles Wilkes lead the way for modern national expeditions

4. The shattered crystalline spheres and the heliocentric revolution: Copernicus, Gilbert, Galileo, Kepler, Newton

5. The heart pump and blood circulation: William Harvey

6. Robert Boyle as the skeptical chemist: John Dalton as the new atomist

7. Unified physics of Galileo, Descartes, and Newton: PRINCIPIA, OPTICS

D. Paradigms Beyond the Empirical

1. Unwritten history of the natural world: James Hutton's THEORY OF THE EARTH, Charles Darwin's ORIGIN OF

SPECIES

2. A century of turmoil over evolution: Thomas Huxley vs. Bishop Wilberforce concluding "By faith we understand that the universe was formed at God's command, so that what is seen was not made out of what was visible."

3. Modern medical science: Oliver Wendell Holmes and sterilization procedures, Louis Pasteur finds germs in the air

4. Present concepts of matter: Plank's quantum, Heisenberg's uncertainty, Gell-Mann's quarks and the eightfold way

5. The new gravity: Albert Einstein's general relativity

6. A changing universe: Fred Hoyle's steady state universe gives way to Edwin Hubble's "Big Bang"

E. A Restless Struggle Toward Multidisciplinary Science

1. The impact of the International Geophysical Year and satellite data on established theories

2. The impact of the DNA molecule and punctuated equilibrium on Darwinian thought; Crick, Watson, and Gould

3. Science as changing laws of men vs. nature wondrously and mercifully maintained by our changeless God

IV. COURSE METHOD AND MATERIALS

A. This course will present most topics by lecture and demonstration. Measurement of general understanding will be made with several essay tests. Several demonstrations and experiments will be developed by the student to show past scientific beliefs. Oral biographies of key scientists will be given by the student. A research paper written by the student will dwell on scientific crises that produce either amended theories or revolutions. Individualized reading assignments will be reviewed and shared orally for the entire class.

B. Textbooks:

Charles Singer, A SHORT HISTORY OF SCIENTIFIC IDEAS TO 1900, Oxford University Press, 1959.

Rom Hare, GREAT SCIENTIFIC EXPERIMENTS: Twenty Experiments that Changed Our View of the World, Oxford University Press, 1983.

Martin Sponholz, SEPARATE FROM HIS WORD, DMLC Print Shop, 1989.

C. Credits: Three.

D. Prerequisites: Science 7001 and Science 7020.

E. History of Science is a required course for the Biology Minor, the Physical Science Minor, and the Secondary Science Major.

F. Offered the second semester of alternate years beginning the second semester of the 1989-1990 school year.

G. Catalog description:

> An overview of science from ancient times to the present using the scientific ideas of people set in their historical times and places with their unforeseen limitations. Success of scientific explanations in their times will be shown by demonstrations and experiments. The change of scientific thought and its process will be emphasized.

H. Current instructor: Prof. Martin P. Sponholz

MSp
10/13/88

APPENDIX II. JUNIOR HIGH SCHOOL MODEL: Scientific Thought, Ninth Grade, Luther High School, Onalaska, Wisconsin, 1971-1982.

Luther High School
Onalaska, Wisconsin

I. COURSE IDENTIFICATION

Science Department; Scientific Thought

This course is an historical and philosophical study of science founded upon Scriptural truths; one credit; prerequisite is an understanding of general science as demonstrated in 8th grade and achievement tests; M. Sponholz, R.Helmreich, O. Mammel, T. Mellon; offered annually.

II. OBJECTIVES

As a first [senior] high school science course [or last junior high school course], this course concentrates on the concepts and methods upon which scientific thought has developed. It emphasizes three of the goals of the science department at Luther.

1. To develop a firm Scriptural foundation in all aspects of the science curriculum

2. To develop a scientifically literate person

3. To provide a base in a wide variety of scientific areas

By the use of a narrative of scientific discoveries, thoughts, and interpretations, this course will attempt to explain why the mainstream of current science is so far afield from God's Word, His Creation, and His maintenance of that Creation.

III. TOPICAL OUTLINE

Sem. I
Foundations of Science

Week 1 An introduction gives the complete outline of the course and reasons for each of the study areas. Since scientific thought uses many books, no single text, and is also to a large extent dependent on additional materials from lectures, a large portion of the first week is spent on methods of taking notes. Practice lectures, samples of ideal notes, and close scrutiny of students are all used to achieve this objective. An individual's notes will be collected until the instructor feels a minimum level of taking notes has been reached.

Week 2-4 A detailed study of the six days of Creation with God overlooking His

complete, perfect, and sinless Creation on the seventh day.

Week 5 Man's fall into sin leads to "Cursed is the ground for thy sake." Only scientific implications of the fall of man are studied. Though God's plan of salvation for man is mentioned, time is not taken to study it thoroughly, but details are left for a concurrent religion class. The Flood.

Week 6 A study of our Lord's miracles, man's superstitions, occult science, and Satan's power will show limits of scientific thought. Not all things should be expected to be explained by human reason.

This completes the foundations of science. Two other major sections covered in scientific thought are history of science and the tools of science. These are studied simultaneously, dividing lecture periods into parts of varying length as subject materials demand.

History of Science

To understand scientific thought one must understand its development since, "The effectiveness of the kind of science we practice today has made men believe that they have found the best way of regarding the world around them: yet in other times they also have thought this and been proved wrong." (Quote by F. Sherwood Taylor, curator of the museum of the history of science, Oxford University, and director of the London Science Museum) Charles Singer, Professor at Oxford University also states, "The science of one age has often become the nonsense of the next."

In order to grasp concepts and developments of scientific thought, classical observations and experiments are made. While an era in scientific thought is being studied, the student must mentally place himself in that era and think as the ancients.

Week 7-9 Earliest science was quite different from a cave man running from fire. A look at Adam's knowledge, Cain and his descendants, earliest astronomy traditions, scientific writings of Thales (624-565 B. C.), the Pythagoreans.

Week 10-18 A Survey of many men's scientific beliefs

Plato
Aristotle
Euclid
Archimedes
Federally funded research at Alexandria
Ptolemy and THE ALMAGEST
Contributions of the Romans

Semester II

Week 1 The Middle Ages

Week 2 An insert of Oriental science

Week 3-6 The great scientific debate concerning our solar system through the

work of Copernicus and Kepler

Week 7-16 The entire field of science is surveyed and brought up to date by studying and reworking key experiments of:

Galileo
Newton
Darwin
Einstein
and many others between

Week 17-18 A broad view of modern science, the direction it is taking, and some guesses of the scientific thoughts of the future

Tools of science

Semester I

Week 7 A study of the scientific method

Week 8 Counting and the use of scientific notation

Week 9-10 Measurements: length, mass, and time

Week 11-12 Manipulation of units--dimensional analysis

Week 13-14 Definition and usefulness of vectors in science. Mathematics is limited to graphical analysis.

Week 15-16 A study of significant figures with respect to observations and measurements

Week 17-18 Errors generated with significant figures; limitations and mathematical manipulation of these errors; practical problems attempt to arrive at total real error involved when gathering several data each with an error.

Semester II

Week 1-4 Extending the basic human senses with instruments; scientific demands and limitations of instruments; a study of errors so generated: response time, parallax, precision, accuracy, human error; extensive lab work on known parameters.

Week 5-10 Statistics--an attempt is made to achieve a mental feeling for the difference between a "sample" and a true "population"; the prediction of the true population from a small sample; validity of statistical inferences.

Week 11-12 Development of mathematical formulas for a measured set of data using graphing and regression techniques; strong correlation with the students' algebra class is made.

Week 13-14 Similar math modeling is demonstrated to students in the 2nd, 3rd,

and 4th dimensions to give the student a grasp of the complexity of a true scientific problem of today.

Week 15-16 Review of past tools of science, limits of observations are studied.

Week 17-18 The true grasp of science attempting to understand the universe; a specific study examining how constant the constants of science are.

One should note both tools of science and history of science, though quite different in approach, become quite intertwined by the last few weeks of the second semester. Scientific thought concludes with Job 38-41. With the Holy Spirit's help, a student concludes with a firm faith in how the worlds were framed and how God continually controls and tenderly cares for it all.

IV. STUDENTS SERVED

All freshmen meeting the prerequisites of this course as determined by freshmen counselors and the science department are required to take scientific thought. It is rated 4-7.

V. CLASSROOM PROCEDURE

Students will meet three periods per week in a large group for lecture. Because of the large number of students, questions and discussion will be prohibited except for questions of clarity. The only format of these large group sessions will be formal lectures. Extensive note taking is required. Two periods per week students report in small groups for open discussion on previous lectures, inspection of notes, occasional lab work performing the major experiments of the ages which influenced scientific thinking, and studying topics which do not lend themselves to formal lecture. As weather permits, several evening astronomy sessions are conducted at all hours of the night depending upon particular phenomena being observed and the weather. The planetarium of the University of Wisconsin at LaCrosse is utilized at least once during the year for the study of displays of the heavens not possible to observe in the short span of the school year.

VI. GENERAL INSTRUCTIONAL METHODS

The taking of notes is the most important learning tool of this course. A respectable grade cannot be earned without respectable notes. Various library reading assignments related to the lectures are assigned, and homework questionnaires guiding these reading assignments are provided. Generally, these questionnaires must be handed in one week from the day they are assigned. Problem sets concerned with the tools of science have the same assignment requirements. Check quizzes are given only during small group sessions when intricate and difficult work merits this kind of check. All quizzes are announced at least one day in advanced. Three major tests requiring a full period are given during the large group sessions at equal intervals throughout a semester. A two hour final exam covering all things learned completes a semester's work. The quarter grade is an advisory grade usually based on at least one major test, homework, and quizzes. The semester grade is a composite of

six equal parts. Each major test counts as one part, the composite of all homework and quizzes count as one part, and the final exam counts as two parts.

VII. REFERENCE BOOKS

THE HOLY BIBLE.
"A History of Science" by M. P. Sponholz, a paper presented to the Southwestern and Mississippi Valley Joint pastor's Conference, 1972.
AN ALMAGEST by M. P. Sponholz, 1973.
AN ILLUSTRATED HISTORY OF SCIENCE by F. Sherwood Taylor, 1965.
SCIENCE OF SCIENCE by R. Fox, M. Garbuny, and R. Hooke, 1963.
SCIENCE AND CREATION by Morris, Boardman, and Koontz, 1971.
THE GENESIS FLOOD by Whitcomb and Morris, 1961.
THE FLOOD by Rehwinkle, 1951.
EXPOSITION OF GENESIS by Leupold, 1942.
THE STRUCTURE OF SCIENTIFIC REVOLUTIONS by T. S. Kuhn, 1970.
THE WORLD AS I SEE IT by A. Einstein, 1934.
A SHORT HISTORY OF SCIENTIFIC THINKING by Singer, 1959.
THE DAWN OF ASTRONOMY by J. N. Lockyer, 1894.

VIII. Date Reported:

August 20, 1973.

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Location numbers are six digets each. The first two digets give the chapter number, the next two digets give the section number, and the last two digets give the paragraph number.

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